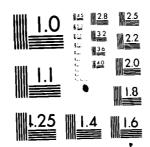
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MICROCOPY RESOLUTION TEST CHART NATIONAL PUREATE OF SAME ARE 100 CA



TECHNICAL REPORT

Volume 2

THE DEVELOPMENT OF PREDICTIVE ENGINEERING FORMULATIONS FOR DIVER HEATING

by

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and

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for

Naval Medical Research and Development Command

and

Office of Naval Research

NOO0 14-79-C-03.79

1982

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APPENDICES

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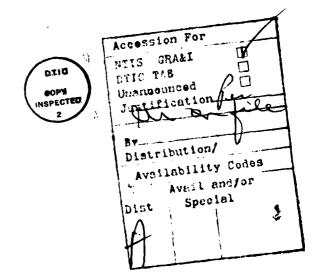
APPENDIX A -

ORGANIZATION OF THE DIRECT ACCESS EXPERIMENTAL DATA FILES:

The first record of each file contains one integer variable (NREC) followed by up to 196 alphanumeric characters. This record is formatted 114,196A1. The variable, NREC, contains the number of discrete experimental times that follow in records 2 through NREC+1. Each of these experimental records has 29 data points associated with it. They are stored in array EXP and are read in by the format 13F8.2,15F6.2,F6.1. The first variable, EXP(1), contains the experimental times; EXP(2) thru EXP(13) contain rates of heat flow from sites 1 to 12; variables EXP(14) thru EXP(25) contain temperatures from sites 1 to 12; variable EXP(26) is the rectal temperature; EXP(27) is the ambient temperature; variable EXP(28) is the Hody mean skin temperature, which is calculated by using the twelve experimental temperatures found in EXP(14) to EXP(25); and EXP(29) contains the Hody mean skin rate of heat flow, which is computed by using the twelve experimental rates of heat flow contained in EXP(2) to EXP(13). The variable names appearing above correspond to the actual names used in the interactive program. The sites referred to as 1 to 12, above, correspond to the segments identified in Figure 2 and Table 1 of Chapter I.

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The name given to an experimental data file is totally up to the user. It is assumed that the user is knowledgeable enough of the file structure and naming conventions prescribed by the computer's operating system that the file names will not be in violation of these conventions. The conventions which apply to the RSX-11M system can be found in Chapter 1 of reference 52.



APPENDIX B

COMPOSITE DATA FILE LISTINGS FOR FILES RHL1AR1, DTP1ART, DTP2AR1, AND DTP3AR1;

Each composite data file has temperature and rate of heat loss data listed for the Head (HEAD), Chest (CHST), Abdomen (ABD), Upper Back (UBAC), Lower Back (LBAC), Arm (ARM), Hand (WRST), Front Thigh (F-TH), Front Calf (FCLF), Rear Thigh (R-TH), Rear Calf (RCLF), and Foot (FOOT) segments. The composite segmental temperature listings also contain the Rectal (RECT) and Ambient (AMB) temperatures. All temperatures are in °C and the rates of heat loss are in watts. The composite data file surface areas are 2.04 M², 1.91 M², 2.017 M² and 1.99M²; and the number of component subjects are 5, 4, 3, and 3; for RHLIARI, DTPIART, DTP2ARI, and DTP3ARI data files, respectively. The composite surface areas were determined by averaging the component subject's surface areas. These files are listed in Tables B.1.A-B.4.B as described below.

Table Number	Contents
B.1.A	RHL1AR1, Temperatures
B.1.B	RHL1AR1, Rates of Heat Loss
B.2.A	DTP1ART, Temperatures
B.2.B	DTP1ART, Rates of Heat Loss
B.3.A	DTP2AR1, Tempe atures
B.3.B	DTP2AR1, Rates of Heat Loss
B.4.A	DTP3AR1, Temperatures
B.4.B	DTP3AR1. Rates of Heat Loss

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	LBAC	3.87	9.04	11. 61	14. 93	14. 97	15. 42	16.94	13.64	15.31	15. 60	13. 63	14.69	17.16	13. 32	13.33	13. 91	14.30	15. 29	13. 63	13.37	12. 72	13.09	13. 33	17. 10	13. 40	14, 29	14. 69	12. 99	16. 79	13. 96	15.87	16. 19	15.05	16.01	15. 33	19.02	14. 63	14. 52	15.94	14, 43	
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(pənu	21. 74 12. 60	
.B, conti	87. 68 85. 83	
(Table B.4.B, continued)	174. 00 176. 00	

(204)

APPENDIX C

DETERMINATION OF THE VISCOSITY (4), THERMAL CONDUCTIVITY (k), AND OTHER PROPERTIES FOR A 95% HELIUM - 5% OXYGEN GAS MIXTURE

To facilitate the selection of correlations for predicting the properties of this binary mixture of nonpolar hallum and oxygen, the behavior of the mixture was investigated by evaluating the component gases to see if they could be treated as perfect gases. To this end, the compressibility factor (Z) of each component was determined from Nelson-Obert generalized compressibility charts [53] with a reduced pressure, P_r , and reduced temperature, T_r , as defined in Equations C.1 and C.2, respectively.

$$P_{r} = \frac{P}{P_{c}} \tag{C.1}$$

where: P = Ambient pressure in ATA

P_C = Critical pressure in ATA

$$T_{r} = \frac{T}{T_{c}} \tag{C.2}$$

where: T = Ambient temperature in °K

 T_{C} = Critical temperature in $^{\circ}K$

(205)

The estimated compressibility factors (Z) as well as the critical and reduced values are listed for each component in Table C.1. The compressibility factors of both helium and oxygen were found to be approximately one (Table C.1), which indicates that these real gases can be assumed to behave

Table C.1

Critical and Reduced Properties, and Compressibility Factor Values for a 95% Helium - 5% Oxygen Mixture at 295.30 °K and 20.89 ATA

<u>Helium</u>	<u> Oxygen</u>
$T_c = 5.3 \text{ °K}$	T _c = 154.8 °K
$P_C = 2.26 ATA$	$P_C = 50.1 ATA$
Tr = 55.72	Tr = 1.91
Pr = 9.24	Pr = 0.42
Z ~ 1.00	Z ≈ 0.99

ideally at the mixture's temperature and pressure. To evaluate the behavior of the mixture, Dalton's Law [53] is applied in terms of compressibility factors for a mixture of ideal gases (Eq. C.3).

$$Z_{m} = \sum_{i=1}^{n} y_{i} Z_{i} \qquad ((.3)$$

where: $Z_m = Mixture compressibility$

 y_i = Mole fraction for component i

 Z_1 = Compressibility factor for pure component i

n = Number of components in mixture

Equation C.4 is reproduced from Obert [53] and expresses the relationship between a mole fraction and a volume fraction.

$$y_{i} = \frac{n_{i}}{n} = \frac{v_{i}}{v} \tag{C.4}$$

where: y_i = Mole fraction of component i

 n_i = Number of moles of component i

n = Number of moles of mixture

 V_i = Partial volume of component i

V = Volume of mixture

 $\frac{V_i}{V}$ • 100 = Percent by volume of component i

For a 95% helium - 5% oxygen mixture, Equation C.4 indicates that the mole fractions are 0.95 for helium and 0.05 for oxygen. With these mole fractions and the compressibility factors (Table C.1) for helium and oxygen, Equation C.3 yields a mixture compressibility factor (Z_m) of 1.004. This result confirms that the mixture may also be treated as ideal.

Examination of a generalized compressibility chart [53], shows that, as the pressure becomes small relative to its critical pressure, the compressibility factor for any value of reduced temperature (Tr) approaches one. This implies that any nonpolar real gas will act ideally if its pressure is low relative to its critical pressure. Analogously, property correlations for low pressure mixtures of nonpolar, real gases may be assumed to yield reasonable values for mixtures at any pressure when the mixture behaves ideally. This conclusion permitted us to select correlations for viscosity (μ) and thermal conductivity (k) which were recommended by Reid and Sherwood [43] for low pressure mixtures of nonpolar real gases.

Viscosity (µ)

Reid and Sherwood [43] suggest that Equation C.5 be used to predict the viscosity (μ_m) of a low pressure binary mixture with the Wilke estimate $(\Phi_{ij}, \text{ Eq. C.6})$ for the Φ_{12} and Φ_{21} terms.

$$\mu_{\rm m} = \frac{\mu_1}{1 + \Phi_{12} (y_2/y_1)} + \frac{\mu_2}{1 + \Phi_{21} (y_1/y_2)} \tag{C.5}$$

where: μ_m = Mixture viscosity

 μ_1, μ_2 = Viscosity of pure components

 $y_1, y_2 = Mole fractions$

$$\Phi_{ij} = \frac{\left[1 + \left(\frac{\mu_i}{\mu_j}\right)^{0.5} \left(\frac{M_j}{M_i}\right)^{0.25}\right]^2}{\sqrt{8} \cdot \left[1 + \left(\frac{M_i}{M_j}\right)\right]^{0.5}}$$
(C.6)

where: $\Phi_{1j} = \Phi_{12}$ and Φ_{21} for Equation C.5

 μ_{j}, μ_{j} = Viscosity of pure components i and j

 M_{j} , M_{j} = Molecular weight of pure components i and j

Table C.2 displays the property values which were substituted into Equations C.5 and C.6 to estimate the mixture viscosity. As indicated in Table C.2, the temperature of the mixture is specified as 295.3 °K (22.15 °C).

Table C.2

Properties Substituted into Equations C.5 and C.6 for a 95% Helium - 5% Oxygen Mixture at 295.3 °K and 307.0 PSIA

	Helium	0xygen
Subscript #	1	2
Mole Fraction	0.95	0.05
Molecular Weight	4.003	32.00
Viscosity (LB/FT·SEC)†	1.326×10^{-5}	1.3944 x 10 ⁻⁵

This temperature represents a mean film temperature selected from the RHL1AR1 data file by taking the average of the highest and lowest film temperatures for all of the regions. Substituting from Table C.2 into Equation C.6 for ϕ_{12} and ϕ_{21} yields 2.3226 and 0.3055, respectively. Equation C.5 produces a mixture viscosity of 1.3865 x 10^{-5} LB/FT·SEC when the ϕ_{ij} values and property values from Table C.2 are substituted.

Thermal Conductivity (k)

From information and recommendations presented by Reid and Sherwood [43], we decided to utilize the binary form of the Wassiljewa equation (Eq. C.7) with the A_{ij} terms which are determined from the Lindsay and Bromley formulation (Eq. C.8).

[†]These values were interpolated from data presented in the <u>U.S. Navy Diving</u> Gas Manual [42].

$$k_{m} = \frac{k_{1}}{1 + A_{12}(y_{2}/y_{1})} + \frac{k_{2}}{1 + A_{21}(y_{1}/y_{2})}$$
 (C.7)

where: k_m = Thermal conductivity of the mixture

 k_1, k_2 = Thermal conductivity of the pure components 1 and 2

 y_1, y_2 = Mole fraction of components 1 and 2

 A_{12}, A_{21} Determined by Equation C.8

$$A_{i,j} = 0.25 \left[1 + \left\{ \left(\frac{\mu_i}{\mu_j} \right) \left(\frac{M_j}{M_i} \right)^{0.75} \left[\left(1 + \frac{S_i}{T} \right) \right] \right\}^{0.5} \right]^2 \cdot \left(1 + \frac{S_{i,j}}{T} \right)$$

$$\left(1 + \frac{S_{i,j}}{T} \right)$$

where: $A_{i,j} = A_{12}, A_{21}$ for Equation C.7

 μ_{1},μ_{1} = Pure component viscosities

 $M_{\hat{1}}, M_{\hat{T}}$ = Pure component molecular weights

T = Absolute temperature of mixture

 S_i , $S_j = 1.5 T_{bi}$ unless component i is He, H₂, or Ne; then $S_i = 79 \text{ }^{\circ}\text{K}$

Thi = Normal boiling point of component i (°K)

 $S_{ij} = S_{ji} = C_s(S_iS_j)^{0.5}$

 C_S ~ 1 unless one of the components is very polar, then C_S ~ 0.733

These equations are valid for nonpolar, real gases and thus reasonable estimates for ideal gases.

Table C.3 displays the values that are necessary to solve for the mixture's thermal cnductivity. Substituting the values from Table C.3 into Equation C.8 yields values for A_{12} and A_{21} of 2.3689 and 0.52399,

respectively. A mixture thermal conductivity of 2.189 x 10^{-5} BTU/SEC*FT°F is obtained when these values and the properties from Table C.3 are substituted into Equation C.7.

Table C.3

Properties for Equations C.7 and C.8 for a
95% Helium ~ 5% Oxygen Mixture at 295.3 °K and 307.0 PSIA

	<u>Helium</u>	0xygen
Subscript #	1	2
Mole Fraction	0.95	0.05
Molecular Weight	4.003	32.000
Thermal Conductivity (BTU/FT·SEC°F)†	2.417×10^{-5}	4.386×10^{-6}
Viscosity (LB/FT·SEC) [†]	1.326×10^{-5}	1.3944 x 10 ⁻⁵
Normal Boiling Point (°K)	4.3	90.0
S (°K)	79.0	135.0
S _{ij} (°K)	103.27	

Other Properties

As previously mentioned, the specific heat, C_p , and the density, ρ , were interpolated from data in reference 42. The interpolations yielded values of 0.94215 BTU/LB°F and 0.2878 LB/FT³ for the specific heat and density, respectively. The volume coefficient of expansion was determined with the ideal gas formulation of the reciprocal of the absolute film temperature. The characteristic length in the Grashof and Nusselt numbers was set equal to the region's length for vertical cylinders and to the region's diameter for horizontal cylinders and spheres. Table C.4 summarizes the properties described above and presents them in SI units.

[†]These values were interpolated from data presented in the $\underline{\text{U.S.}}$ Navy Diving Gas Manual [42].

Table C.4

Properties Necessary to Determine Grashof, Prandtl, and Nusselt Numbers for a 95% Helium - 5% Oxygen Mixture at 22.15 °C and 200 MSW

Specific Heat (C_p) 3.945 x 10^{+3} J/KG°K

Density (ρ) 4.610 KG/M³

Viscosity (μ) 2.063 x 10⁻⁵ KG/M·SEC

Thermal Conductivity (k) $1.364 \times 10^{-1} \text{ W/M}^{\circ}\text{K}$

7

APPENDIX D ----

INTERACTIVE PROGRAM DOCUMENTATION ~

The interactive program and associated documentation have been developed on a Digital Equipment Corporation's (DEC) PDP 11/60 computer which executes the RSX-11M operating system. The program was written in DEC's FORTRAN IV-PLUS language [54,55], and the PLXY-11M Software [50] was used in generating all associated plots. To implement this code on another computer or operating system will require the availability of a FORTRAN compiler with compatible plotting software and personnel capable of understanding and modifying the interactive program's code. Such personnel should be able to resolve any differences which might exist between DEC's FORTRAN IV-PLUS version and the new system's version of the FORTRAN language. Any differences encountered should be limited to the 'OPEN' and 'CLOSE' statements used to access input and output files and to the subroutine calls used in accessing the plotting software.

The information presented in this interactive model program has been developed and verified with accepted principles of engineering analysis.

These developments may be found in the Chapters I-VII of this document. The constants specified for the garment ensemble are taken from the Navy's

prototype Diver Thermal Protection (DTP) garment. The references to corrected predicted overall heat transfer coefficient (OHTC) indicate that these values are corrected by use of an empirically derived biasing factor. The development of these factors is found in Chapter VII. The references to uncorrected OHTC indicate that the empirical biasing factors have not been applied to the predicted values.

Program Source Code

This interactive diver heat loss program has been written in DEC's FORTRAN IV-PLUS language and utilizes DEC's PLXY-11M plotting software for producing data plots. A flow chart of the program is included as Appendix E, and the actual FORTRAN source code listing is presented in Appendix F. The source code has been internally documented by use of comment statements. In the DEC FORTRAN IV-PLUS language, comments are specified in two manners: the placement of a "C" in column 1 indicates a comment line and the presence of an exclamation point ('!') in columns 7 thru 72 indicates that what follows is a comment. Both of these methods have been used within the program code to allow blocking of information. An experienced research engineer, knowledgeable in FORTRAN programming, should be able to understand and modify the program code with the assistance of the documentation that follows. Any modifications to the program source code without prior written approval of the authors is the sole responsibility of the user.

Creation of an Executable Task

As implied previously, this documentation assumes that the interactive program is to be assembled on a DEC computer which executes an RSX-11M operating system that includes a FORTRAN IV-PLUS compiler. Translation of the source program is performed with the FORTRAN IV-PLUS compiler (F4P) by the command line:

MCR>F4P HLMOD.OBJ, HLMOD.LST=HLMOD.FTN †

This command specifies an object file, HLMOD.OBJ; a listing file, HLMOD.LST; and the source code file, HLMOD.FTN. Further information on the F4P command and the operation of this compiler is available in reference 55.

The translation step completed, an executable task can now be created. This step is accomplished by using the Task Builder (TKB), a program for linking object files and resolving symbol references. The command used to invoke the TKB task follows.

MCR>TKB
TKB>HLMOD.TSK,=HLMOD.OBJ,[1,1]PLTUSL/LB
TKB>/
ENTER OPTIONS:
TKB>MAXBUF=292
TKB>ACTFIL=5
TKB>//

The MAXBUF option is specified to allow input and output file record lengths greater than 132 characters (bytes). The ACTFIL=5 option allows five files to be open simultaneously. This is necessary when creating plots to compare

[†]Each command line is terminated by striking RETURN.

experimental and predicted data. The input file, HLMOD.OBJ, created by the F4P step, is converted into a runable task, HLMOD.TSK, with all the necessary system supplied subroutines linked into the Main module. The second input file, [1,1]PLTUSL/LB, is the system library containing the object modules for the PLXY-11M plotting subroutines. Further documentation on TKB can be found in references 55 and 56.

The file, HLMOD.TSK, can now be run to estimate supplementary heating requirements for the resting diver. To initiate execution, the RUN task is employed by the command:

MCR>RUN HLMOD.TSK

This command loads the interactive heat loss program into memory and initiates its processing.

Running the Interactive Model Program

The diver heat loss program was written for two different modes of execution: production and research. In the production mode, predicted regional heat flux and supplementary heating are calculated from data supplied about the diver's posture, the body region of interest, the number of finite difference nodes per region, a design mean skin temperature, and the ambient depth and temperature. The values of predicted overall heat transfer coefficient (OHTC) are always corrected by applying the empirically derived biasing factors before calculating the predicted regional heat flux and supplementary heating. The research mode duplicates the production mode but also allows the comparison of predicted and experimental temperatures, heat

fluxes, and overall heat transfer coefficients. The comparisons are performed by using either corrected or uncorrected predicted values. In this mode, the predicted values of regional skin temperature are calculated by using a mean skin temperature derived from the experimental segmental skin temperatures. The experimental data used for comparison is always stored in a direct access data file [54] which is organized as described in Appendix A of this document.

The first question asked on the interactive terminal is:

1 ARE YOU A RESEARCH USER ? (Y,N,X) .

If you respond with a 'Y' (yes), then the program will execute the research mode, while if you enter 'N' (no), the production mode will be executed. The 'X' (exit) response is provided to allow the user to terminate execution. When the user responds to this question, the program stores the answer in the variable REU. Thus REU will contain either 'Y', 'N', or 'X'.

Since the production mode questions are a partial subset of the research mode questions, both sets will be presented at the same time with REU=Y used to designate the research mode and REU=N to indicate the production mode. Each question will be numbered, and the flow through the questions will be indicated by logic statements. For example, if a group of questions is processed in only the production mode, you will then be instructed to go to

the next question asked by the research mode or both modes. The logic statement would appear as:

IF REU=N GO TO 9

where the trailing number indicates the next appropriate question. The single difference in the logic for a research mode only question would be REU=Y instead of REU=N. Questions not covered by a logic statement are applicable to both modes.

The layout (column and line spacing) of the questions presented below closely matches that which appears on an interactive video terminal during execution of the program. This correspondence was preserved to make the questions appear as realistic as possible and thus give the unfamiliar user an idea of what to expect when running the program. The only difference in the appearance of this document and the video terminal is that the first line of each question has been displaced to allow the inclusion of the documentation's question number.

Question Flow

To present the question flow completely, the first question is repeated:

1 ARE YOU A RESEARCH USER ? (Y,N,X) †

As indicated previously, a 'Y' (yes) response causes the program to execute the research mode, while an 'N' (no) response causes the production

[†]The response to each question is terminated by striking RETURN.

mode to be executed. An 'X' (exit) response causes the program to terminate and returns the user to the operating system's control. If the user wishes to do additional computing, the program must be initiated by issuing the RUN HLMOD.TSK instruction again.

IF REU=N GO TO 4

2 DO YOU WISH TO CORRECT PREDICTED 'U' VALUES ? (Y/N)

A 'Y' (yes) response sets REU=S, which indicates that the research mode is being executed and that all overall heat transfer coefficient values, U, are to be corrected by applying the biasing factors (See Chapter VII for details.). An 'N' (no) response indicates that the U values are to be left uncorrected. This response leaves REU set equal to 'Y' (yes) which implies execution of the research mode with uncorrected overall heat transfer coefficient values.

3 DO YOU WISH DEBUG PRINTS: ? (Y/N):

A 'Y' (yes) response will activate certain print statements used to output information useful in diagnosing possible program errors. An 'N' (no) reply causes these debugging prints to remain inactive.

4 ENTER DEPTH IN (M)SW, (F)SW OR (P)SIG BY (M#,F#,P#): [F]

The expected response is the ambient depth of immersion expressed in meters of seawater (MSW), feet of seawater (FSW), or pounds per square inch gage (PSIG). The units are indicated by an M, F, or P which precedes the

number (i.e., M200.0 indicates 200 MSW). The depth specified must be \leq 76.2 MSW, \leq 250 FSW, or \leq 111.37 PSIG to remain within the range of tabulated thermal conductivity values. Since the model was developed by using data from air compensated dry suits, this maximum depth was chosen to match the normal limit specified by the U.S. Navy for air diving [46].

The '[F]' (floating point) notation appearing at the end of question 4 and '[I]' (integer) notation appearing at the end of question 10 are examples of the designations used to indicate the type of number, real or integer, that is expected as a response. The '[F]' and '[I]', respectively, indicate that the expected response is a real or integer number. These notations appear on questions where a numeric response is required that is not specified in the list of possible choices.

The 'R' and 'X' responses of questions 5 thru 8 perform similar functions in each question. The 'R' response causes the program to re-initialize all of the displayed data to the initial program's assigned values. The values presented in each question are the program's assigned values used in the interactive model. This option is provided to allow the user to test special values and then return to the program's assigned data without terminating and rerunning the interactive program. An 'X' response is entered when no changes are desired or when all modifications are completed. The program then proceeds to the next question.

5 SEA LEVEL GARMENT ENSEMBLE PROPERTIES

1-SPECIFIC THERMAL RESISTANCE OF UNDERGARMENT: (CLO/CM)
2-27
2-UNIT THICKNESS OF UNDERGARMENT: (CM)
3-THICKNESS OF OUTER GARMENT: (CM)
4-THERMAL CONDUCTIVITY OF OUTER GARMENT: (W/M*C)
ENTER (1-4) TO ALTER, (R) TO REINITIALIZE, (X) FOR NO CHANGE:

Question five asks the user to verify the assumed sea level garment ensemble properties. If a selection is made, the program collects the new value and then re-displays the question.

The region names and ID numbers indicated in questions 6 thru 8 correspond to the numbered regions appearing in Figure 1 (Chapter I).

Additionally, whenever a change is indicated in response to these questions, the program will collect the indicated value and then re-display the complete question.

6 REGIONAL UNDERGARMENT THICKNESS (CM)

			UNIT	ACTUAL
ID#	REGION	MULTIPLIER	THICKNESS	THICKNESS
1	HEAD	1.00 *	1.63 =	1.6300
2	TORSO	1.00 *	1.63 =	1.6300
3	ABDOMEN	1.00 *	1.63 =	1.6300
4	THIGH	1.00 *	1.63 =	1.6300
5	CALF	1.00 *	1.63 =	1.6300
6	F00T	2.00 *	1.63 =	3.2600
7	UP ARM	1.00 *	1.63 =	1.6300
8	LOW ARM	1.00 *	1.63 =	1.6300
9	HAND	1.00 *	1.63 =	1.6300

ENTER (1-9) TO ALTER, (R) TO REINITIALIZE, (X) FOR NO CHANGE:

This question allows the user to change the assumed regional undergarment thicknesses by entering a new multiplier for each of the nine regions. The unit thickness appearing above is entry 2 of question five (UNIT THICKNESS OF UNDERGARMENT: (CM)) and is the nominal value associated with the Navy's DTP garment.

7 ALLOWABLE REGIONAL HEAT FLUX (W/M**2)

		ALLOWABLE
ID#	REGION	HEAT FLUX
ï	HEAD	23.30
2	TORSO	60.00
3	ABDOMEN	49.70
4	THIGH	42.40
5	CALF	85.00
6	F00T	97.00
7	UP ARM	98.90
8	LOW ARM	125.25
9	HAND	265.86

ENTER (1-9) TO ALTER, (R) TO REINITIALIZE, (X) FOR NO CHANGE:

Here the user is given the opportunity to verify and modify the assumed regional allowable heat fluxes. To modify a specific region, enter the appropriate number. The program will prompt for a new value and then re-display the table.

8 REGIONAL BIASING FACTORS (DIMENSIONLESS)

ID#	REGION	BIASING FACTOR
1	HEAD	2.63
2	TORSO	2.63
3	ABDOMEN	2.27
4	THIGH	3.50
5	CALF	3.21
6	F00T	12.70
7	UP ARM	2.29
8	LOW ARM	2.19
9	HAND	3.49

ENTER (1-9) TO ALTER, (R) TO REINITIALIZE, (X) FOR NO CHANGE:

This question allows the operator to modify our empirical regional biasing factors. To change a region's value, enter the corresponding ID #.

The program will prompt for a new value and then re-display the question. The derivation of these biasing factors may be found in Chapter VII.

9 WRITE OUTPUT FILE WHERE: (T=SCREEN,F=DMPDAT.LST)

Both the production and research modes automatically create a detailed output file which is enhanced when the debug option has been activated. This statement asks where to print the output file. The 'T' response, which indicates the 'SCREEN', refers to the terminal at which the program is running. The 'F' answer, which refers to 'DMPDAT.LST', indicates the name of the file which is created on the user's default system device [55,57].

10 ENTER # NODES: [I]

This question allows you to change the number of finite difference nodes from one node to any reasonable number per region. This ability is of little value when comparing predicted and experimental data unless the experimental values are recorded at multiple sites per region. We suggest that the # NODES be specified as one until more detailed segmental temperature and heat flux data is available. This option has been included in the code to allow the operator to investigate the effects of small changes in pressure on the garment ensemble's overall thermal resistance. The upper limit on the number of nodes is left to the user's discretion. The number can be no greater than 9999 (limit of computer variable), but practicality and the lengths of the regions suggest a number approximately equal to 100.

IF REU=N GO TO 14

11 DO YOU WISH TO COMPARE T,Q,U VALUES WITH EXP'T DATA: (Y/N)

The answer to this question determines whether the research mode compares experimental and predicted values. A 'Y' (yes) response instructs the computer to compare experimental and predicted values, while an 'N' (no) response indicates that no comparison is to be performed. These responses are stored in the variable OCOMP. This variable is introduced to facilitate subsequent logic since it controls the processing of certain questions (See question 12.). When a comparison is performed, the design mean skin temperature is automatically set equal to the experimental mean skin temperature which is determined from Hody's equation (Eq. 8) with the segmental experimental temperatures. (See Chapters II and IV.) The ambient temperature is set equal to the experimental value. Thus, it is unnecessary to collect a design mean skin temperature (question 14) or an ambient temperature (question 15). If a negative response is entered for this question, the program automatically jumps to question 14. (Note: If plots of the experimental and predicted data (question 18) are to be produced, a 'Y' (yes) response must be tendered here.)

IF OCOMP=N GO TO 14

12 ENTER TOTAL SURFACE AREA OF EXP'T SUBJECT (M**2): [F]

The comparison of predicted and experimental values is performed in terms of a heat flux (W/M^2) . However, the experimental data is stored as a rate of heat loss and therefore, must be divided by the segmental surface area for conversion to a heat flux before being compared. The segmental surface area

is found by multiplying the subject's total surface area by the corresponding Hody segmental surface fraction (Table 1 of Chapter I). In our case, the experimental values represent the average of at least three subject's data which was recorded in various unit systems. These values were converted to a common base system, rates of heat loss in watts, before being averaged.

13 ENTER EXPERIMENTAL DATA FILE NAME:

Enter the name of the direct access file containing the experimental data to be compared. This direct access file must be organized and formatted as specified in Appendix A.

After processing questions 12 and 13, it is known that QCOMP equals a 'Y' (yes); therefore, the program must skip questions 14 and 15 and proceed directly to question 16 (as indicated above in question 11).

IF QCOMP=Y GO TO 16

14 ENTER DESIGN MEAN SKIN TEMPERATURE (C): [F]

Enter the mean skin temperature value that is to be used as the design goal for indicating thermal safety. The value entered here must be \leq 32 °C and \geq 26 °C to remain within the mean skin temperature range defined for the regional skin temperature prediction model. (See Chapter IV for details.) This question is skipped if a comparison is performed. Instead, the Hody mean skin temperature calculated from the segmental experimental skin temperatures is used.

15 ENTER AMBIENT TEMPERATURE >= 1.0 (C): [F]

Enter the ambient temperature to be used as the design value. The ambient temperature must be ≥ 1.0 °C to remain within the temperature limits defined for the boundary layer fluid properties. (See Chapter VI.) When a comparison is performed, question 15 is skipped, and instead, the experimental ambient temperature is used.

16 SELECT BODY REGION (1-9) OR (0) FOR ALL REGIONS: [I]

A response of one through nine corresponds to regions 1 to 9 of the model man (Fig. 1), respectively, and specifies that calculations will be performed for that region only. An answer of zero instructs the program to perform the heat loss calculations for all regions without recalling any of these questions.

17 SELECT POSTURE OF SUBJECT (0-SIT,1-STAND,2-PRONE): [I]

This is the last question asked by both modes. The program is designed to accommodate a sitting, standing, or prone, resting subject. The response given here designates which posture is to be assumed for the calculations.

At this point, all necessary information has been collected, and the program proceeds by calculating and outputting the predicted regional heat flux and required supplementary heating within the constraints of the parameters specified above. If the program is executing in the production mode (REU=N), then all predicted values of overall heat transfer coefficient (OHTC) are corrected by applying experimentally derived biasing factors. (See Chapter VII.) If the research mode is being executed, then the predicted OHTC

values are either left uncorrected (REU=Y) or corrected by using the experimentally derived biasing factors (REU=S). If a comparison of predicted and experimental data is being conducted, the program calculates the experimental comparison variables and then asks if plots are desired. (See Figures D.1-D.5 for examples of the computer generated plots.) If no comparative plots are to be generated, the program returns to question 1.

IF QCOMP=N GO TO 1

18 DO YOU WISH TO PLOT T'S, Q'S, AND U'S? (Y/N)

If a 'Y' (yes) is entered, the program proceeds by asking questions which concern the plot scales and then produces three regional plots which compare dimensional, predicted and experimental values as a function of time. The three plots generated are for regional skin temperature (T in °C), heat flux (Q in W/M^2), and overall heat transfer coefficient (U in W/M^2 °C). An 'N' (no) response indicates no dimensional plots are to be produced, and the program proceeds to question 21. The tendered response is stored in variable PLD.

IF PLD=N GO TO 21

The scale factors which are displayed for verification and possible change in questions 19, 20, 22, and 23 are all real numbers. Thus any new value which may be entered must also be real.

19 Y-AXIS SCALE FACTORS

	LY	SY	ΙY
T C	5.00	20.00	4.00
Q W/M2	5.00	0.00	50.00
U W/M2*C	4.00	0.00	4.00

SELECT: (1=T,2=Q,3=U,X=NO MORE CHANGES)

This question gives the user the opportunity to alter the assumed y-axis scale factors of length (LY), starting value (SY), and increment (IY) used for the dimensional T, Q, and U plots. If a number between one and three (corresponding to skin temperature (°C), heat flux (W/M^2), and overall heat transfer coefficient (W/M^2 °C), respectively) is entered, the program will prompt for the indicated scale factors and then re-display the question. An 'X' (exit) is entered when no changes are desired or when all changes are completed.

20 X-AXIS (TIME) SCALE FACTORS

LX SX IX

T,Q,U MIN 7.00 0.00 20.00

CHANGE X-AXIS? (Y/N)

This question allows the operator to modify the x-axis (time-axis) scale factors. There is only one set of x-axis scale factors for the dimensional skin temperature, heat flux, and overall heat transfer coefficient figures. This is done because all of the plots are generated from the same set of experimental temperature and rate of heat loss data. If a 'Y' (yes) is tendered, the program will prompt the entry (separated by commas) of the time-axis scale factors of length (LX), starting value (SX), and increment (IX) in the units of minutes. An 'N' (no) response will cause the program to continue using the assumed values.

The y-axis scales shown in question 19 and the x-axis scale of question 20 were used to develop the plots displayed in Figures D.1-D.3. The listings of data in Tables D.5-D.7 are produced as the corresponding plot is generated and are stored in the output files discussed below. Each tabulation lists all the data plotted in the respective figure.

The program proceeds to generate the intermediate vector files used by the DEC PLXY-11M plotting routines [50] and the corresponding output files. The three intermediate vector and output files produced are named COMPAR.VEC;N and COMPAR.OUT;M, respectively, where N and M are version numbers assigned by the operating system. The temperatures are plotted and outputted in COMPAR.VEC;N and COMPAR.OUT;M, followed by the heat fluxes in COMPAR.VEC;N+1 and COMPAR.OUT;M+1, and then the overall heat transfer coefficients in COMPAR.VEC;N+2 and COMPAR.OUT;M+2. The vector files must then be manually converted to interpretable graphs by running the PLTCTL.TSK program. Details on this program are contained in reference 50. The interpretable graphs and their corresponding output files may be directed to a hard copy printer using the RSX-11M tasks PIP or PRI detailed in reference 52.

21 DO YOU WISH TO PLOT NORMALIZED T'S AND BIOT #'S ? (Y/N)

If a 'Y' (yes) is entered, the program proceeds by asking questions which concern the plot scales and then produces regional plots which compare non-dimensional predicted and experimental values as a function of time. The two plots generated for each region are for regional normalized skin temperature (TN) and Biot number (BI). An 'N' (no) response indicates no dimensionless plots are to be produced, and the program returns to question 1. The tendered response is stored in variable PLN.

IF PLN=N GO TO 1

22 Y-AXIS SCALE FACTORS NON-DIMENSIONAL T'S & U'S

LY SY IY
TN 4.00 0.50 0.25
BI 4.00 0.00 10.00

SELECT: (1=TN,2=BI,X=NO MORE CHANGES)

This question gives the user the opportunity to alter the assumed y-axis scale factors used for the non-dimensional TN and BI plots. If either 1 or 2 (corresponding to normalized skin temperature (TN) and Biot number (BI), respectively) is entered, the program will prompt for the indicated scale factors and will then re-display the question. An 'X' (exit) is entered when no changes are desired or when all changes are completed.

23 X-AXIS (TIME) SCALE FACTORS

LX SX IX
TN,BI MIN 7.00 0.00 20.00

CHANGE X-AXIS? (Y/N)

This question allows the operator to modify the x-axis (time-axis) scale factors. There is only one set of x-axis scale factors for the non-dimensional normalized skin temperature and Biot number graphs. This was done because all of the plots were generated from the same set of experimental temperature and rate of heat loss data. If a 'Y' (yes) is tendered, the program will prompt the entry (separated by commas) of the time-axis scale factors of length (LX), starting value (SX), and increment (IX) in units of minutes. An 'N' (no) response will cause the program to continue using the assumed values.

The y-axis scales shown in question 22 and the x-axis scale of question 23 were used to develop the plots displayed in Figures D.4 and D.5. The listings of data in Tables D.8 and D.9 are produced as the corresponding plot is generated. Each tabulation lists all the data plotted in the respective figure.

The program proceeds to generate the intermediate vector files used by the DEC PLXY-11M plotting routines [50] and the corresponding data output files. The two intermediate vector and output files produced are named COMPARN.VEC;N and COMPARN.O''T;M, respectively, where the trailing N and M are version numbers assigned by the operating system. The normalized temperatures are plotted and outputted in COMPARN.VEC;N and COMPARN.OUT;M, followed by the Biot numbers in COMPARN.VEC;N+1 and COMPARN.OUT;M+1. The vector files must then be manually converted to interpretable graphs by running the PLTCTL.TSK program. Details on this program are contained in reference 50. The interpretable graphs and their corresponding output files may be directed to to a hard copy printer using the RSX-11M tasks PIP and PRI which are detailed in reference 52.

As previously indicated, the dimensional plots of temperature, heat flux, and overall heat transfer coefficient and the non-dimensional plots of normalized temperature and Biot number are generated collectively for any specified region. These groupings were chosen rather than allowing selective plotting of a specific parameter since the overall heat transfer coefficients (U) and Biot numbers (BI) are functions of the regional temperature and heat flux. This dependence of the U's and BI's indicated the desirability of the other plots to verify the integrity of the computational routines. This arrangement allows plots of specific regional parameters to be produced by printing only the desired graph, yet retain the advantages offered by verification.

Example Production and Research Runs

The question numbers of the previous section will be used to denote the question corresponding to the indicated response. For the production mode example, design conditions of ambient temperature, depth, and design mean skin temperature were chosen to be representative of the model's design goals. The experimental data used in the research mode example is considered representative of the calibrated data available. The question flow, Table D.1, and output, Table D.2, correspond to the production mode example. The question flow, Table D.3, and outputs, Tables D.4-D.9, and Figures D.1-D.5 represent the research mode example. Further discussion of these outputs follows the figures.

Table D.1
Production Mode Question Flow

Question	# Re	sponse
1	#с	N
2		NAT
3		NA
4		F10.0
3 4 5		X
6		x
7		x
8		Ŷ
9		Ê
		1
10		
11		NA
12		NA
13		NA
14		30.0
15		5.0
16		3
17		2
18		NA
19		NA
20		NA
21		NA
22		NA
23		NA

Table D.2
Sample Production Mode Output

BODY REGION: POSTURE: 0=SIT,1=STAND,2=PRONE DESIGN MEAN SKIN TEMPERATURE: REFERENCE DEPTH: AMBIENT TEMPERATURE:	30.00 C 10.00 FSW 5.00 C
PREDICTED TEMPERATURE FOR REGION 3: CORRECTED PREDICTED OHTC FOR REGION 3: PREDICTED UNIT HEAT FLUX FOR REGION 3: ALLOWABLE UNIT HEAT FLUX FOR REGION 3: REQUIRED SUPPLEMENTARY HEAT FLUX: PREDICTED RATE OF HEAT LOSS FOR REGION 3: ALLOWABLE RATE OF HEAT LOSS FOR REGION 3: REQUIRED SUPPLEMENTARY HEATING:	30.31 C 3.96 W/M**2*C 100.25 W/M**2 49.70 W/M**2 50.55 W/M**2 33.35 WATTS 16.54 WATTS 16.82 WATTS

 $^{^\}dagger NA$ indicates Not Appropriate, used to indicate an unasked question.

Table D.3
Research Mode Question Flow

Question #	Response
1	Y
2	N
3	N
4	F10.0
5	X
1 2 3 4 5	X
7	X
8	
9	X F 1
10	1
11	Ÿ
12	1.91
13	DTP1ART.DAT [†]
14	NA
15	NA
16	3
17	2
18	Υ
19	χtt
20	N
21	Y
22	X
23	Ñ
	**

 $^{^\}dagger$ This file specification corresponds to the experimental data. The format used in this direct access file is explained in Appendix A.

^{††}To produce Figures D.3 and D.8, the scale factors for the U's in question 19 must be changed to LY = 4.0, SY = 0.0, IY = 2.0 from LY = 4.0, SY = 0.0, IY = 4.0.

Table D.4

Sample Research Mode Output

BODY REGION: POSTURE: 0=SIT,1=STAND,2=PRONE DESIGN MEAN SKIN TEMPERATURE: REFERENCE DEPTH: AMBIENT TEMPERATURE:	3 34.03 C 10.00 FSW 3.93 C
PREDICTED TEMPERATURE FOR REGION 3: UNCORRECTED PREDICTED OHTC FOR REGION 3: PREDICTED UNIT HEAT FLUX FOR REGION 3: ALLOWABLE UNIT HEAT FLUX FOR REGION 3: REQUIRED SUPPLEMENTARY HEAT FLUX: PREDICTED RATE OF HEAT LOSS FOR REGION 3: ALLOWABLE RATE OF HEAT LOSS FOR REGION 3: REQUIRED SUPPLEMENTARY HEATING: WGT'ED EXP'T TEMP'S, SITES 3, 5; FOR REGION 3: WGT'ED EXP'T OHTC'S, SITES 3, 5; FOR REGION 3: WGT'ED EXP'T HEAT FLUX, SITES 3, 5; FOR REGION 3:	34.34 C 1.75 W/M**2*C 53.23 W/M**2 49.70 W/M**2 3.53 W/M**2 17.71 WATTS 16.54 WATTS 1.17 WATTS 34.11 C 0.50 W/M**2*C 15.14 W/M**2

EXPERIMENTAL TIME: 3.00

BODY REGION: POSTURE: O=SIT,1=STAND,2=PRONE DESIGN MEAN SKIN TEMPERATURE: REFERENCE DEPTH: AMBIENT TEMPERATURE:	3 34.59 C 10.00 FSW 3.95 C
PREDICTED TEMPERATURE FOR REGION 3: UNCORRECTED PREDICTED OHTC FOR REGION 3: PREDICTED UNIT HEAT FLUX FOR REGION 3: ALLOWABLE UNIT HEAT FLUX FOR REGION 3: REQUIRED SUPPLEMENTARY HEAT FLUX: PREDICTED RATE OF HEAT LOSS FOR REGION 3: ALLOWABLE RATE OF HEAT LOSS FOR REGION 3: REQUIRED SUPPLEMENTARY HEATING: WGT'ED EXP'T TEMP'S, SITES 3, 5;† FOR REGION 3: WGT'ED EXP'T OHTC'S, SITES 3, 5;† FOR REGION 3: WGT'ED EXP'T HEAT FLUX, SITES 3, 5;† FOR REGION 3:	34.90 C 1.75 W/M**2*C 54.21 W/M**2 49.70 W/M**2 4.51 W/M**2 18.04 WATTS 16.54 WATTS 1.50 WATTS 34.58 C 0.34 W/M**2*C 10.23 W/M**2

 $^{^{\}dagger}$ Sensor sites (3,5) refer to the experimental segments of Figure 2 and Table 1.

Figure D.1. Plots of Experimental (T-EXPT) and Predicted (T-PRED) Temperatures (°C) for the Abdomen.



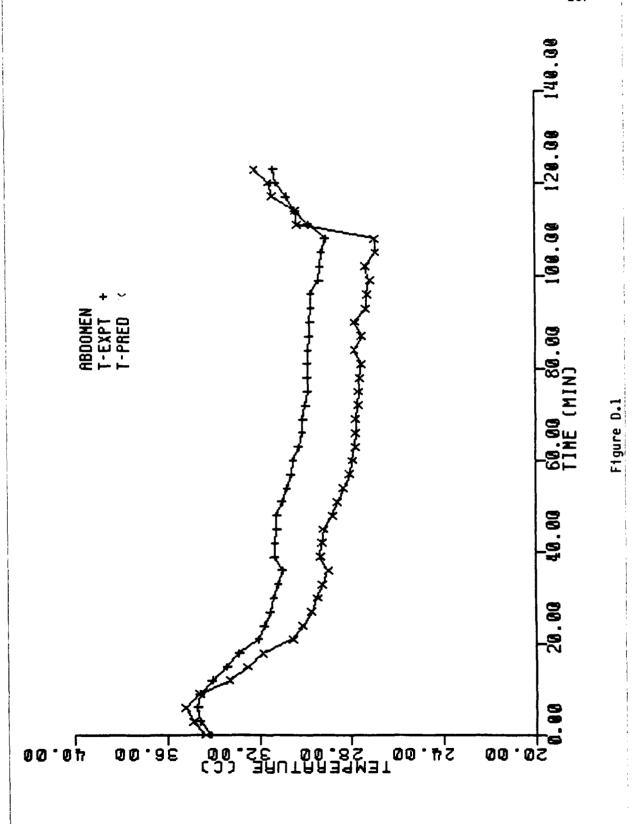


Table D.5

Experimental (T-EXPT) and Predicted (T-PRED) Temperature Values (°C) as a Function of Time as Plotted in Figure D.1.

ABDOMEN LY: 5.00 * INDICATES TIME	SY: 20.00 IY: POINT NOT PLOTTED; ITS T-EXPT	
0.00	34.11	34.34
3.00	34.58	34.90
6.00	34.68	35.20
9.00	34.59	34.61
12.00	34.05	33.31
15.00	33.41	32.52
18.00	32.87	31.83
21.00	32.04	30.53
24.00	31.79	30.12
27.00	31.52	29.73
30.00	31.36	29.49
33.00	31.16	29.25
36.00	31.00	29.00
39.00	31.33	29.34
42.00	31.31	29.26
45.00	31.20	29.17
48.00	31.20	28.80
51.00	30.97	28.59
54.00	30.77	28.32
57.00	30.59	28.06
60.00	30.50	27.95
63.00	30.25	27.81
66.00	30.10	27.78
69.00	30.07	27.77
72.00	29.94	27.67
75.00	29.86	27.65
78.00	29.86	27.60
81.00	29.85	27.50
84.00	29.83	27.83
87.00	29.78	27.50
90.00	29.74	27.79
93.00	29.70	27.31 27.27
96.00	29.69	
99.00	29.35	27.13 27.35
102.00	29.30	
105.00 108.00	29 . 22 29 . 06	26.89 26.91
111.00	29.00 29.79	30.28
114.00	29.79 30.34	30.28
117.00	30.73	31.32
120.00	31.17	31.50
123.00	31.28	32.10
123.00	71120	JE110

Figure D.2. Plots of Experimental (Q-EXPT) and Uncorrected Predicted (Q-PRED) Heat Flux (W/ M^2) for the Abdomen.

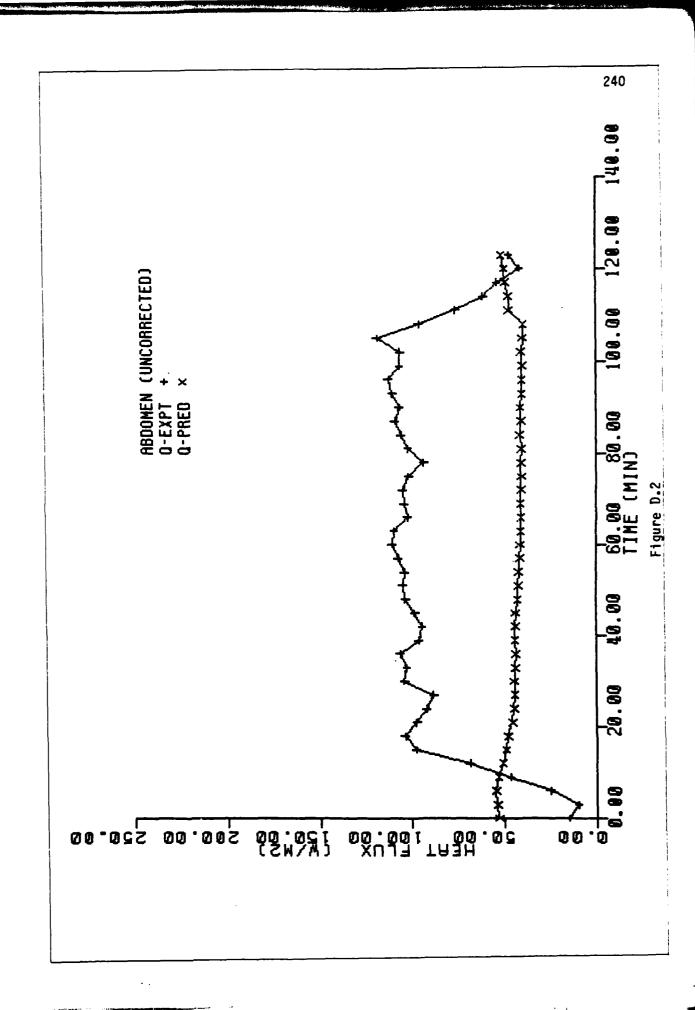
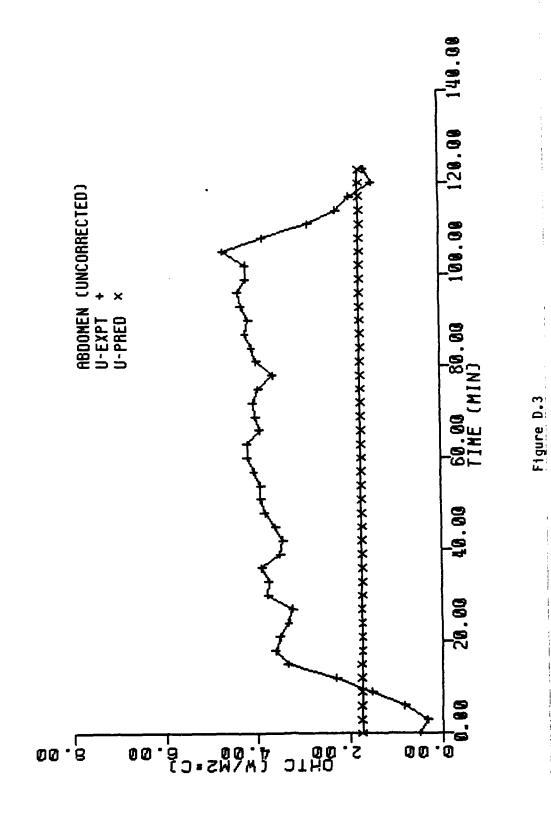


Table D.6

Experimental (Q-EXPT) and Uncorrected Predicted (Q-PRED) Heat Flux Values (W/M 2) as a Function of Time as Plotted in Figure D.2.

ABDOMEN (UNLY: 5.00 * INDICATES TIME	CORRECTED) SY: 0.00 IY: 50 POINT NOT PLOTTED; ITS VO	0.00 ALUE IS <= 0 OR < SY Q-PRED
0.00	15.14	53.23
3.00	10.23	54.21
6.00	25.58	54.85
9.00	46.88	53.56
12.00	68.93	51.02
15.00	97.95	49.46
18.00	103.87	48.26
21.00	97.71	45.70
24.00	92.36	45.11
27.00	88.23	44.31
30.00	104.17	44.63
33.00	102.86	44.15
36.00	106.27	43.71
39.00	96.51	44.35
42.00 45.00	94.45	44.03 43.89
48.00	98.43 103.46	43.89 42.75
51.00	103.46	42.75 42.44
54.00	104.77	41.97
57.00	107.14	41.49
60.00	110.64	41.29
63.00	109.53	41.04
66.00	102.29	41.03
69.00	104.05	40.96
72.00	104.65	40.73
75.00	101.63	40.75
78.00	93.55	40.67
81.00	102.05	40.38
84.00	105.58	41.28
87.00	108.81	40.64
90.00	106.54	41.11
93.00	110.13	40.24
96.00	112.22	40.23
99.00	106.15	39.91
102.00	105.88	40.37
105.00 108.00	118.15 95.47	39.55 39.39
111.00	75 . 90	47.11
114.00	60 . 94	47.15
117.00	53.52	48.99
120.00	40.99	49.46
123.00	46.82	50.99
12000	TO 10 E	00177

Figure D.3. Plots of Experimental (U-EXPT) and Uncorrected Predicted (U-PRED) Overall Heat Transfer Coefficient (OHTC in W/M 2 °C) for the Abdomen.



;

Table D.7

Experimental (U-EXPT) and Uncorrected Predicted (U-PRED) Overall Heat Transfer Coefficient Values (W/M 2 °C) as a Function of Time as Plotted in Figure D.3.

ABDOMEN (UNC LY: 4.00 * INDICATES TIME	CORRECTED) SY: 0.00 IY: 2.0 POINT NOT PLOTTED; ITS VALU U-EXPT	
* INDICATES	POINT NOT PLOTTED; ITS VALU	E IS <= 0 OR < SY
99.00 102.00 105.00 108.00 111.00 114.00 117.00 120.00 123.00	4.19 4.18 4.67 3.82 2.83 2.23 1.93 1.45	1.73 1.73 1.73 1.73 1.73 1.73 1.74 1.74

Figure D.4. Plots of Experimental Normalized (TN-EXPT) and Predicted Normalized (TN-PRED) Temperatures for the Abdomen.

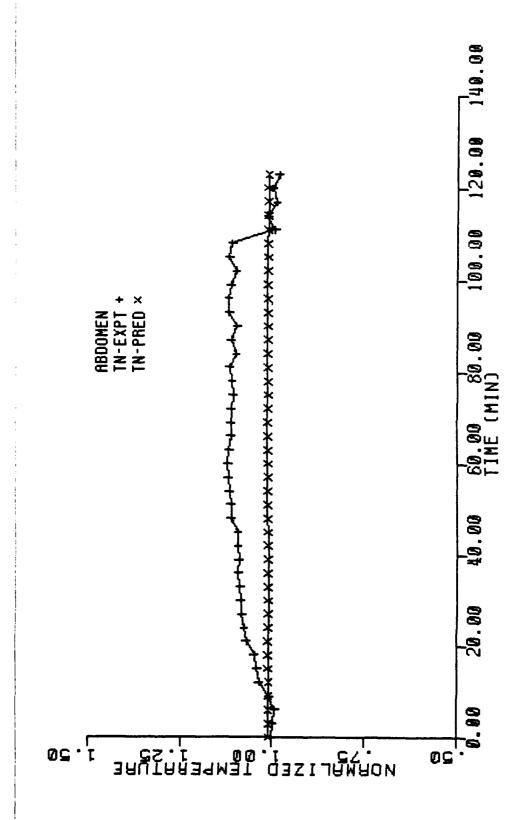


Figure D.4

Table D.8

Experimental (TN-EXPT) and Predicted (TN-PRED) Normalized Temperature Values (Dimensionless) as a Function of Time as Plotted in Figure D.4.

ABDOMEN		25
LY: 4.00	SY: 0.50 IY: 0	.25 LUE 15 /= 0 0R / SY
	POINT NOT PLOTTED; ITS VA	TN-PRED
TIME	IM-EXF	
0.00	1.00	1.01
3.00	1.00	1.01
6.00	0.99	1.01
9.00	1.01	1.01
12.00	1.04	1.01
15.00	1.04	1.01
18.00	1.05	1.01
21.00	1.07	1.01 1.01
24.00	1.08 1.08	1.01
27.00	1.09	1.01
30.00 33.00	1.09	1.01
36.00	1.09	1.01
39.00	1.09	1.01
42.00	1.09	1.01
45.00	1.09	1.01
48.00	1.11	1.01
51.00	1.11	1.01
54.00	1.12	1.01
57.00	1.12	1.01 1.01
60.00	1.12	1.01
63.00	1.12 1.11	1.01
66.00	1.11	1.01
69.00 72.00	1.11	1.01
75 . 00	1.11	1.01
78.00	1.11	1.01
81.00	1.12	1.01
84.00	1.10	1.01
87.00	1.11	1.01
90.00	1.10	1.01
93.00	1.12	1.01
96.00	1.12	1.01
99.00	1.11	1.01 1.01
102.00	1.10 1.12	1.01
105.00	1.12	1.01
108.00 111.00	0.99	1.01
114.00	1.01	1.01
117.00	0.99	1.01
120.00		1.01
123.00		1.01

Figure D.5. Plots of Experimental Biot (BI-EXPT) and Uncorrected Predicted Biot (BI-PRED) Numbers for the Abdomen.

Figure 0.5

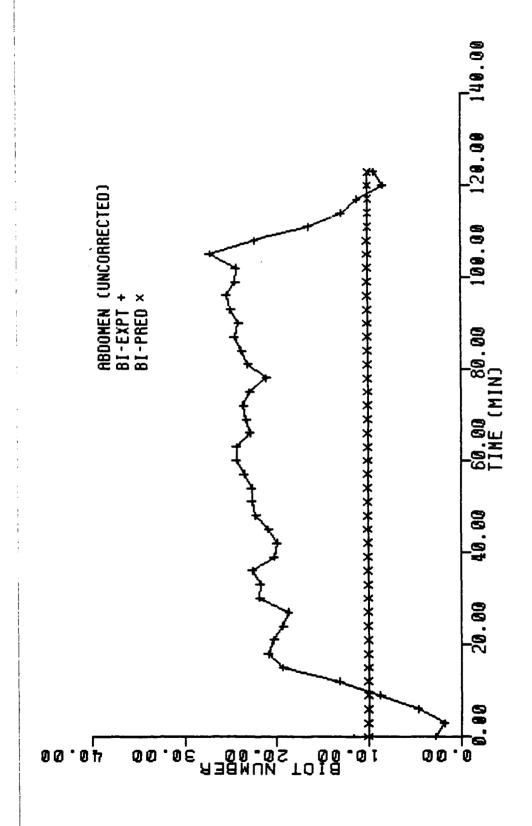


Table D.9

Experimental (BI-EXPT) and Uncorrected Predicted (BI-PRED) Biot Number Values (Dimensionless) as a Function of Time as Plotted in Figure D.5.

ABDOMEN (UNC		10.00	
LY: 4.00 * INDICATES	SY: 0.00 IY:		
	POINT NOT PLOTTED; ITS		
TIME	BI-EXPT	BI-PRED	
0.00	2.89	10.11	
3.00	1.94	10.11	
6.00	4.80	10.11	
9.00	8.86	10.11	
12.00	13.29	10.11	
15.00	19.39	10.11	
18.00	20.94	10.11	
21.00	20.39	10.11	
24.00	19.37	10.10	
27.00	18.75	10.10	
30.00	21.87	10.09	
33.00	21.79	10.09	
36.00	22.66	10.09	
39.00	20.28	10.09	
42.00	19.96	10.09	
45.00	20.88	10.09	
48.00	22.18	10.10	
51.00	22.62	10.10	
54.00	22.66	10.10	
57.00	23.47	10.10	
60.00	24.32	10.10	
63.00	24.31	10.10	
66.00	22.77	10.10	
69.00	23.23	10.10	
72.00	23.52	10.10	
75.00	22.88	10.10	
78.00	21.03	10.19	
81.00	23.05	10.10	
84.00	23.68	10.09	
87.00	24.46	10.09	
90.00	24.03	10.09	
93.00	24.90	10.09	
96.00	25.30	10.09	
99.00	24.37	10.09	
102.00	24.32	10.09	
105.00	27.17	10.09	
108.00	22.24	10.09	
111.00	16.47	10.07	
114.00	12.96	10.07	
117.00	11.22	10.08	
120.00	8.41	10.07	
123.00	9.41	10.06	

Both the production and research runs assume that the diver was in a prone position, and the data calculated in both cases was for the abdomen, region 3 (Fig. 1). The prone posture was chosen since the wet experimental data was recorded from mostly prone divers. The abdomen was used since it is one of the principal regions for which the experimental data was considered reliable. Thus, this region should provide an accurate basis for comparison of our predicted values with the experimental ones.

Table D.2 is the only output generated by the production mode, and Table D.4 is the comparable research mode output. Comparison of Tables D.2 and D.4 reveals that the parameters printed are basically the same except that Table D.2 refers to the overall heat transfer coefficient (OHTC) as corrected, where Table D.4 refers to it as uncorrected; Table D.4 also includes the experimental data and the time at which the data was recorded. Only the first two of fifty-six time increments taken from the experimental study DTP1ART are shown in Table D.4. Figures D.1-D.3 are the regional dimensional skin temperature, heat flux, and overall heat transfer coefficient plots, respectively, produced to display the comparison between dimensional experimental and predicted data. The data actually plotted in Figures D.1-D.3 is listed in Tables D.5-D.7, respectively. Figures D.4 and D.5 are the regional non-dimensional normalized skin temperature and Biot number plots, respectively, which are produced to display the comparison between dimensionless experimental and predicted data. The data actually plotted in Figures D.4 and D.5 is listed in Tables D.8 and D.9, respectively. Figures D.1-D.5 and Tables D.5-D.9 can be produced only when a comparison of temperatures, heat fluxes, and overall heat transfer coefficients is indicated by a 'Y' (yes) response to question 11. These plots have no counterpart in the production mode.

The assumed scale factors displayed in questions 19, 20, 22, and 23 were chosen to allow direct comparisons between regions and across studies. The assumed y-axis scales will handle all of the non-anomalous data taken from the three wet, air breathing studies which were used in verifying this diver heat loss program. The assumed x-axis scales, as ted, accommodate two of the experimental studies and will handle the other study if the axis length (LX) is increased.

The examples shown here are two of the primary reports produced by the program, but they are not the only variations possible. By selectively answering certain questions negatively instead of affirmatively and vise versa, the operator may cause different forms of output to be generated. For example, if the response to question 2 is a 'Y' (yes) in the research mode question flow (Table D.3) sample, then the overall heat transfer coefficients are corrected by applying the biasing factors and Figures D.6-D.10 and Tables D.10-D.15 are produced instead of Figures D.1-D.5 and Tables D.4-D.9, respectively. If questions 18 or 21 were answered with 'N' (no), then no dimensional or non-dimensional plots, respectively, would be produced. In both modes if the number of nodes (question 10) is entered as a value greater than one, then the output files would show the results of the computations for each node.

Table D.10

Sample Research Mode Output With Corrected Overall Heat Transfer Coefficients

EXPERIMENTAL TIME: 0.00

BODY REGION:	3 2
POSTURE: 0=SIT,1=STAND,2=PRONE	2
DESIGN MEAN SKIN TEMPERATURE:	34.03 C
REFERENCE DEPTH:	10.00 FSW
AMBIENT TEMPERATURE:	3.93 C
PREDICTED TEMPERATURE FOR REGION 3:	34.34 C
CORRECTED PREDICTED OHTC FOR REGION 3:	3.97 W/M**2*C
PREDICTED UNIT HEAT FLUX FOR REGION 3:	120.83 W/M**2
ALLOWABLE UNIT HEAT FLUX FOR REGION 3:	49.70 W/M**2
REQUIRED SUPPLEMENTARY HEAT FLUX:	71.13 W/M**2
PREDICTED RATE OF HEAT LOSS FOR REGION 3:	40.20 WATTS
ALLOWABLE RATE OF HEAT LOSS FOR REGION 3:	16.54 WATTS
REQUIRED SUPPLEMENTARY HEATING:	23.66 WATTS
WGT'ED EXP'T TEMP'S, SITES 3, 5; FOR REGION 3:	34.11 C
WGT'ED EXP'T OHTC'S, SITES 3, 5; FOR REGION 3:	0.50 W/M**2*C
WGT'ED EXP'T HEAT FLUX, SITES 3, 5; FOR REGION 3:	

EXPERIMENTAL TIME: 3.00

BODY REGION:	. 3
POSTURE: 0=SIT,1=STAND,2=PRONE	2
DESIGN MEAN SKIN TEMPERATURE:	34.59 C
REFERENCE DEPTH:	10.00 FSW
AMBIENT TEMPERATURE:	3.95 C
PREDICTED TEMPERATURE FOR REGION 3:	34.90 C
CORRECTED PREDICTED OHTC FOR REGION 3:	3.98 W/M**2*C
PREDICTED UNIT HEAT FLUX FOR REGION 3:	123.06 W/M**2
ALLOWABLE UNIT HEAT FLUX FOR REGION 3:	49.70 W/M**2
REQUIRED SUPPLEMENTARY HEAT FLUX.	73.36 W/M**2
PREDICTED RATE OF HEAT LOSS FOR REGION 3:	40.94 WATTS
ALLOWABLE RATE OF HEAT LOSS FOR REGION 3:	16.54 WATTS
REQUIRED SUPPLEMENTARY HEATING:	24.41 WATTS
WGT'ED EXP'T TEMP'S, SITES 3, 5; FOR REGION 3:	34.58 C
WGT'ED EXP'T OHTC'S, SITES 3, 5; FOR REGION 3:	0.34 W/M**2*C
WGT'ED EXP'T HEAT FLUX, SITES 3, 5; FOR REGION 3:	10.23 W/M**2

 $^{^{\}dagger}$ Sensor sites (3,5) refer to the experimental segments of Figure 2 and Table 1.

Figure D.6. Plots of Experimental (T-EXPT) and Predicted (T-PRED) Temperatures (°C) for the Abdomen.

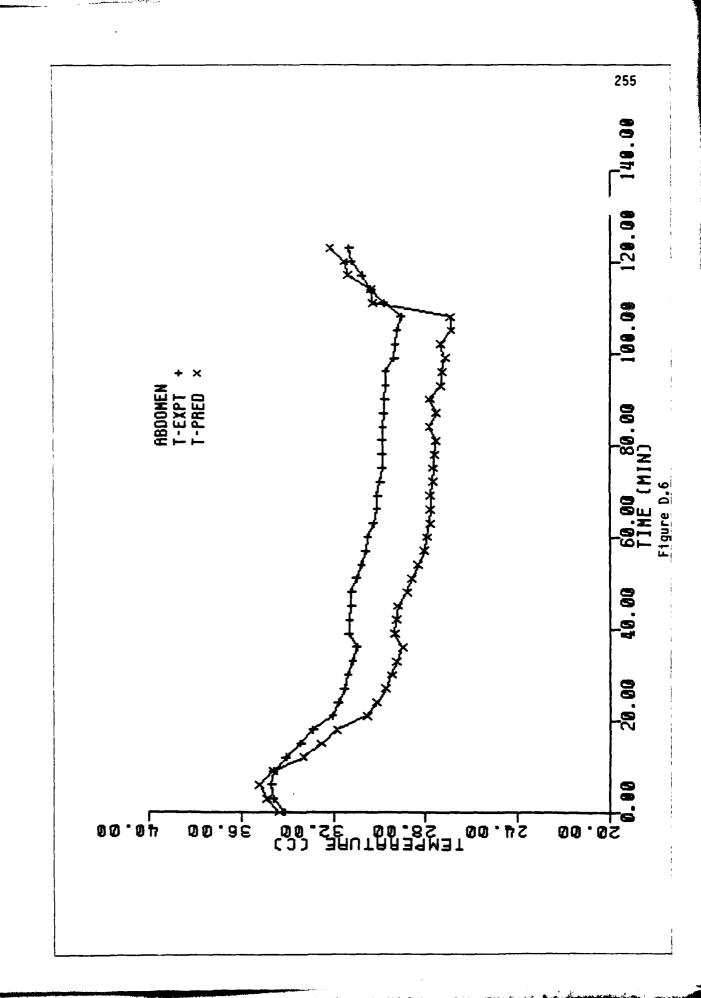


Table D.11

Experimental (T-EXPT) and Predicted (T-PRED) Temperature Values (°C) as a Function of Time as Plotted in Figure D.6.

0.00 34.11 34.34 3.00 34.58 34.90 6.00 34.68 35.20 9.00 34.59 34.61 12.00 34.05 33.31 15.00 33.41 32.52 18.00 32.87 31.83 21.00 32.04 30.53
6.00 34.68 35.20 9.00 34.59 34.61 12.00 34.05 33.31 15.00 33.41 32.52 18.00 32.87 31.83 21.00 32.04 30.53
9.00 34.59 34.61 12.00 34.05 33.31 15.00 33.41 32.52 18.00 32.87 31.83 21.00 32.04 30.53
12.00 34.05 33.31 15.00 33.41 32.52 18.00 32.87 31.83 21.00 32.04 30.53
15.00 33.41 32.52 18.00 32.87 31.83 21.00 32.04 30.53
18.00 32.87 31.83 21.00 32.04 30.53
21.00 32.04 30.53
24.00 31.79 30.12
27.00 31.52 29.73
30.00 31.36 29.49
33.00 31.16 29.25
36.00 31.00 29.00 30.00 31.33 30.34
39.00 31.33 29.34 42.00 31.31 29.26
45.00 31.20 29.17
48.00 31.20 28.80
51.00 30.97 28.59
54.00 30.77 28.32
57.00 30.59 28.06
60.00 30.50 27.95
63.00 30.25 27.81 66.00 30.10 27.78
69.00 30.07 27.77
72.00 29.94 27.67
75.00 29.86 27.65
78.00 29.86 27.60
81.00 29.85 27.50
84.00 29.83 27.83
87.00 29.78 27.50 90.00 29.74 27.79
93.00 29.70 27.31
96.00 29.69 27.27
99.00 29.35 27.13
102.00 29.30 27.35
105.00 29.22 26.89
108.00 29.06 26.91
111.00 29.79 30.28 114.00 30.34 30.31
114.00 30.34 30.31 117.00 30.73 31.32
120.00 31.17 31.50
123.00 31.28 32.10

Figure D.7. Plots of Experimental (Q-EXPT) and Corrected Predicted (Q-PRED) Heat Flux (W/M^2) for the Abdomen.

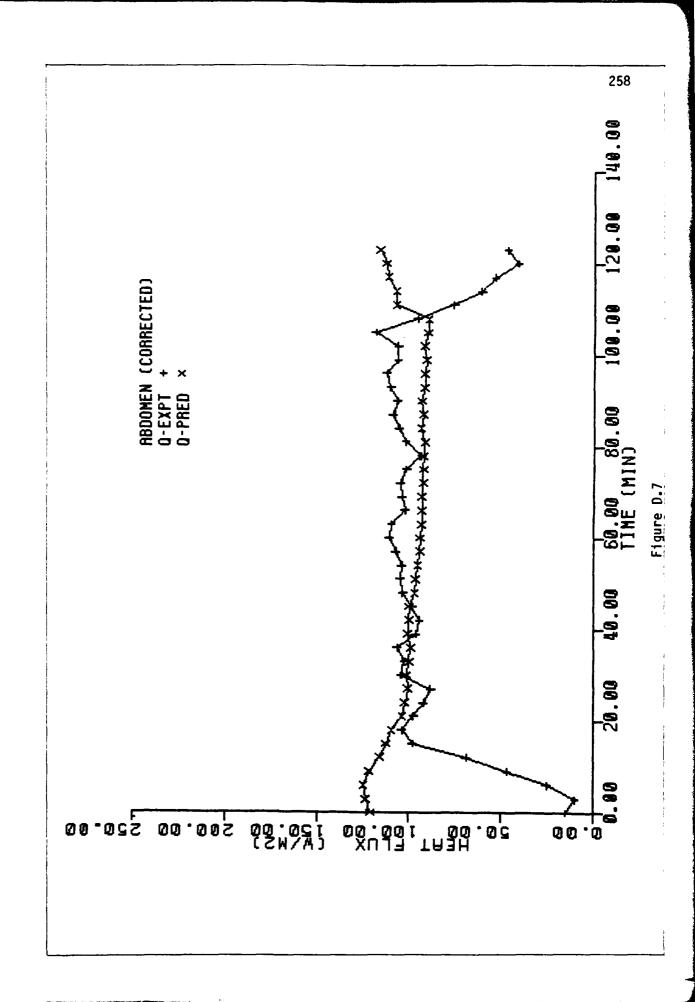


Table D.12

Experimental (Q-EXPT) and Corrected Predicted (Q-PRED) Heat Flux Values (W/M 2) as a Function of Time as Plotted in Figure D.7.

ABDOMEN (CO		
LY: 5.00	SY: 0.00 IY:	50.00
		TS VALUE IS <= 0 OR < SY
TIME	Q-EXPT	Q-PRED
0.00	15.14	120.83
3.00	10.23	123.06
6.00	25.58	124.52
9.00	46.88	121.58
12.00	68.93	115.81
15.00	97.95	112.28
18.00	103.87	109.56
21.00	97.71	103.73
24.00	92.36	102.39
27.00	88.23	100.58
30.00	104.17	101.32
33.00	102.86	100.23
36.00	106.27	99.23
39.00	96.51	100.68
42.00 45.00	94.45 98.43	99 . 94 99 . 63
48.00	103.46	97 . 05
51.00	103.40	96.34
54.00	104.05	95.26
57.00	107.14	94.18
60.00	110.64	93.74
63.00	109.53	93.17
66.00	102.29	93.15
69.00	104.05	92.99
72.00	104.65	92.47
75.00	101.63	92.51
78.00	93.55	92.32
81.00	102.05	91.66
84.00	105.58	93.71
87.00	108.81	92.26
90.00	106.54	93.31
93.00	110.13	91.34
96.00	112.22	91.33
99.00	106.15	90.60
102.00	105.88	91.64
105.00 108.00	118.15	89.78
111.00	95 .47 75 . 90	89.41 106.94
114.00	60 . 94	107.03
117.00	53.52	111.20
120.00	40.99	112.28
123.00	46.82	115.76
123.00	70.02	113.70

Figure D.8. Plots of Experimental (U-EXPT) and Corrected Predicted (U-PRED) Overall Heat Transfer Coefficient (OHTC in W/M 2 °C) for the Abdomen.

Figure D.8

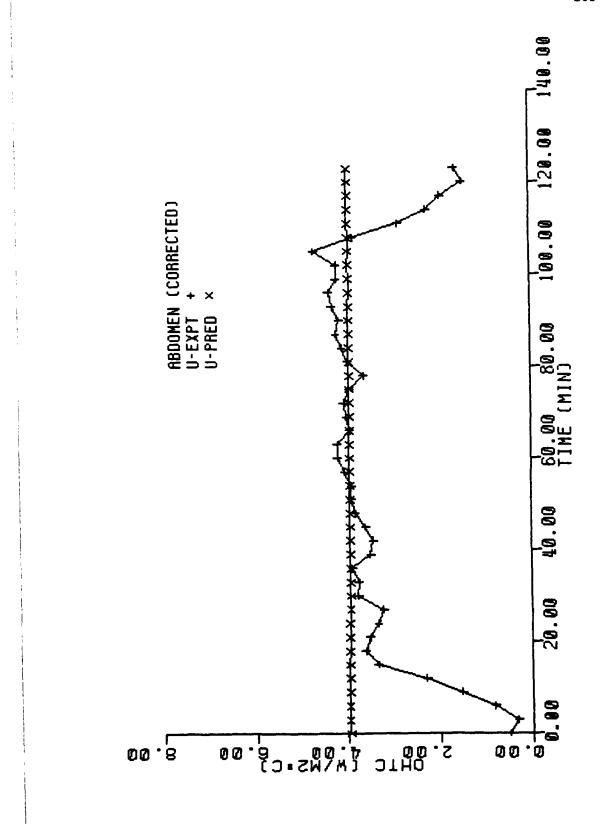
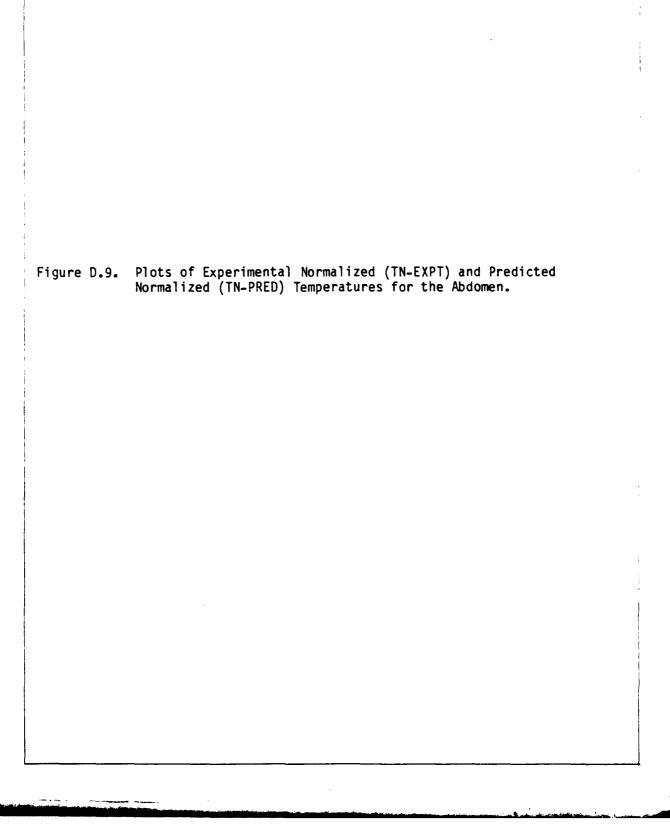


Table D.13

Experimental (U-EXPT) and Corrected Predicted (U-PRED) Overall Heat Transfer Coefficient Values (W/M 2 °C) as a Function of Time as Plotted in Figure D.8.

ABDOMEN (CON LY: 4.00 * INDICATES TIME	RRECTED) SY: 0.00 IY: POINT NOT PLOTTED; ITS V U-EXPT	2.00 ALUE IS <= 0 OR < SY U-PRED
LY: 4.00 * INDICATES TIME 0.00 3.00 6.00 9.00 12.00 15.00 18.00 21.00 24.00 27.00 30.00 33.00 36.00 39.00 42.00 45.00 48.00 57.00 60.00 63.00 66.00 69.00	SY: 0.00 IY: POINT NOT PLOTTED; ITS V U-EXPT 0.50 0.34 0.83 1.53 2.30 3.36 3.62 3.52 3.52 3.34 3.24 3.77 3.76 3.91 3.50 3.44 3.60 3.83 3.90 3.91 4.05 4.19 4.19 3.92 4.00	ALUE IS <= 0 OR < SY U-PRED 3.97 3.98 3.98 3.98 3.97 3.97 3.97 3.95 3.95 3.95 3.95 3.94 3.94 3.94 3.94 3.94 3.94 3.94 3.94
72.00 75.00 78.00 81.00 81.00 87.00 90.00 93.00 96.00 99.00 102.00 105.00 111.00 114.00 117.00 120.00	4.05 3.94 3.62 3.97 4.08 4.21 4.14 4.29 4.35 4.19 4.18 4.67 3.82 2.83 2.23 1.93 1.45 1.62	3.93 3.93 3.93 3.93 3.93 3.93 3.93 3.93





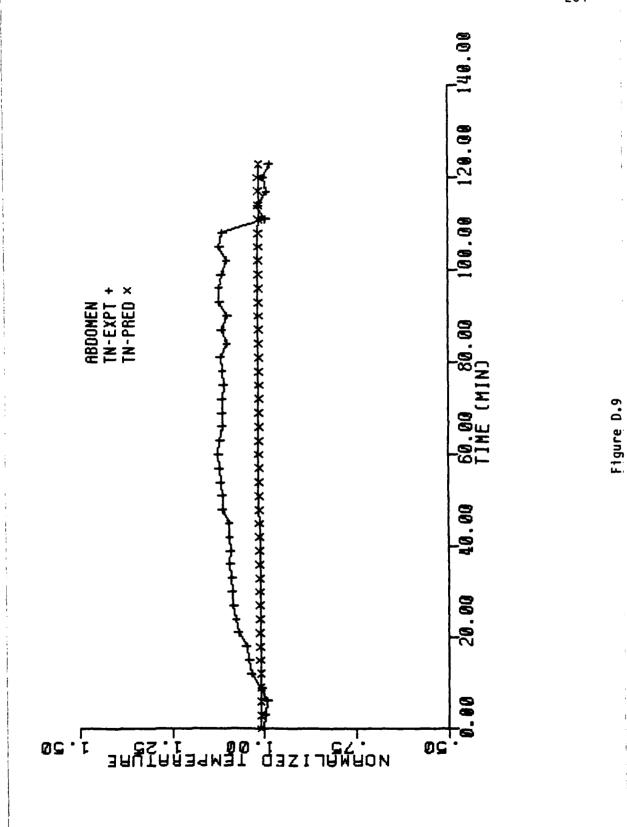


Table D.14

Experimental (TN-EXPT) and Predicted (TN-PRED) Normalized Temperature Values (Dimensionless) as a Function of Time as Plotted in Figure D.9.

ABDOMEN LY: 4.00 * INDICATES TIME	SY: 0.50 IY: 0.25 POINT NOT PLOTTED; ITS VALUE TN-EXPT	
0.00	1.00	1.01
3.00	1.00	1.01
6.00	0.99	1.01
9.00	1.01	1.01
12.00	1.04	1.01
15.00	1.04	1.01
18.00	1.05	1.01
21.00	1.07	1.01
24.00 27.00 30.00 33.00	1.07 1.08 1.08 1.09 1.09	1.01 1.01 1.01 1.01
36.00 39.00 42.00 45.00	1.09 1.09 1.09 1.09 1.09	1.01 1.01 1.01 1.01
48.00	1.11	1.01
51.00	1.11	1.01
54.00	1.12	1.01
57.00	1.12	1.01
60.00	1.12	1.01
63.00	1.12	1.01
66.00	1.11	1.01
69.00	1.11	1.01
72.00	1.11	1.01
75.00	1.11	1.01
78.00	1.11	1.01
81.00	1.12	1.01
84.00	1.10	1.01
87.00	1.11	1.01
90.00	1.10	1.01
93.00	1.12	1.01
96.00	1.12	1.01
99.00	1.11	1.01
102.00	1.10	1.01
105.00	1.12	1.01
108.00	1.11	1.01
111.00	0.99	1.01
114.00	1.01	1.01
117.00	0.99	1.01
120.00	1.00	1.01
123.00	0.98	1.01



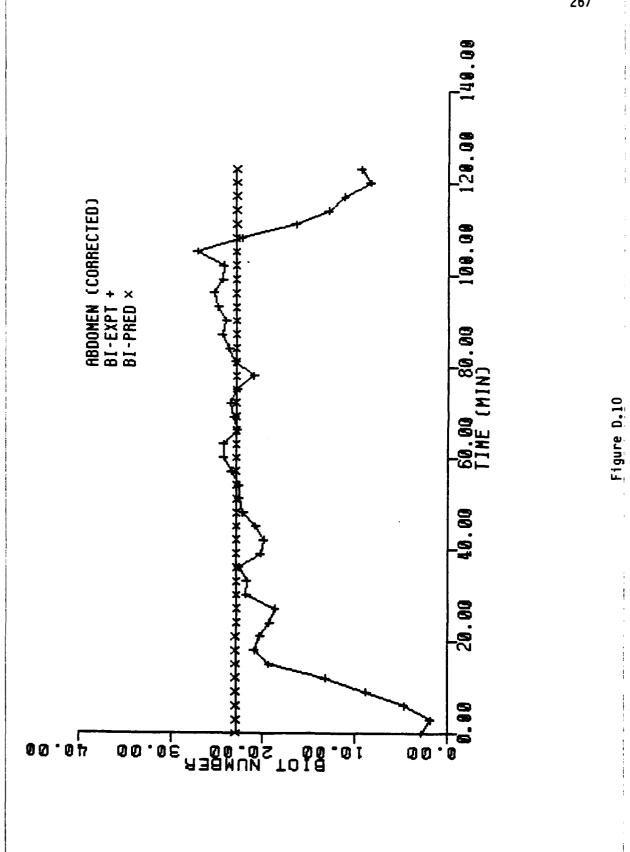
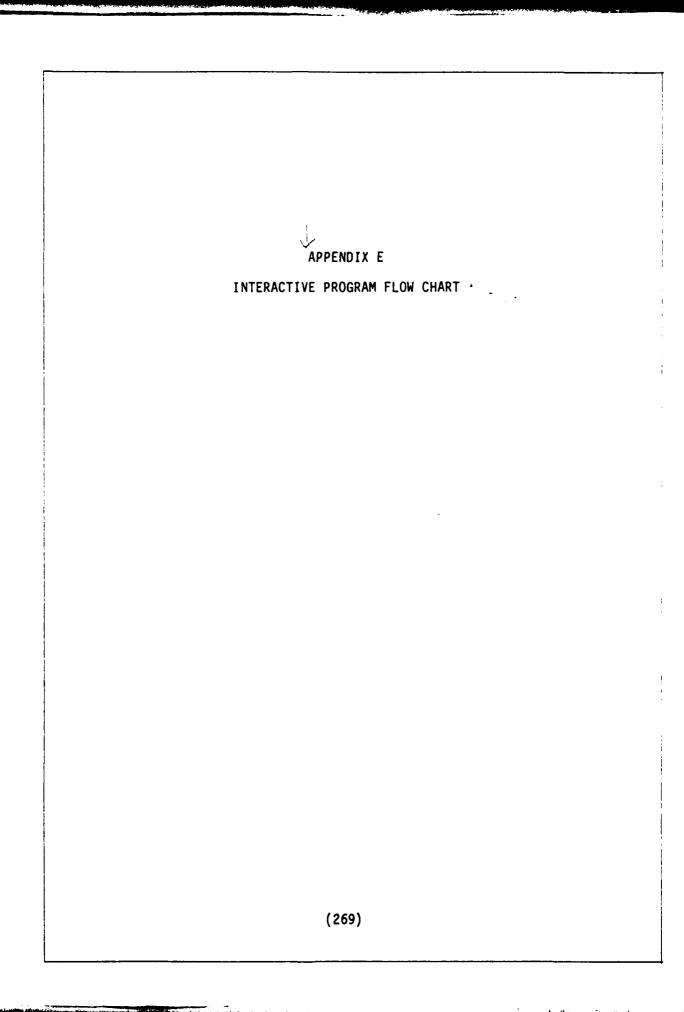


Table D.15

Experimental (BI-EXPT) and Corrected Predicted (BI-PRED) Biot Number Values (Dimensionless) as a Function of Time as Plotted in Figure D.10.

ABDOMEN (COR LY: 4.00 * INDICATES TIME	RRECTED) SY: 0.00 IY: POINT NOT PLOTTED; ITS BI-EXPT	
0.00	2.89	22.94
3.00	1.94	22.94
6.00	4.80	22.94
9.00	8.86	22.94
12.00	13.29	22.94
15.00	19.39	22.94
18.00	20.94	22.94
21.00	20.39	22.94
24.00	19.37	22.93
27.00	18.75	22.93
30.00	21.87	22.91
33.00	21.79	22.91
36.00	22.66	22.91
39.00	20.28	22.91
42.00	19.96	22.91
45.00	20.88	22.91
48.00	22.18	22.93
51.00	22.62	22.92
54.00	22.66	22.92
57.00	23.47	22.92
60.00	24.32	22.92
63.00	24.31	22.92
66.00	22.77	22.92
69.00	23.23 23.52	22 . 92 22 . 92
72.00 75.00	22.88	22.92
78 . 00	21.03	22.92
81.00	23.05	22.92
84.00	23.68	22.91
87.00	24.46	22.91
90.00	24.03	22.92
93.00	24.90	22.91
96.00	25.30	22.91
99.00	24.37	22.91
102.00	24.32	22.91
105.00	27.17	22.91
108.00	22.24	22.91
111.00	16.47	22.87
114.00	12.96	22.87
117.00	11.22	22.87
120.00	8.41	22.87
123.00	9.41	22.84



Main Program

Define body dimensions, properties of air, temperature prediction coefficients, suit properties, allowable regional heat flux, correlation between 12 segment Hody map and 9 region model, plotting variables, and various dependent variables.

1[†] Determine if operator is a research or production user. (REU=Y-Research, N-Production, X-Terminate program)

IF REU=X STOP

IF REU=N GO TO 4

- 2 Determine if corrected or uncorrected overall heat coefficients are desired. (If corrected set REU equal to S otherwise do not alter.)
- 3 Determine if debug prints are desired.
- 4 Input ambient depth and units as M,F,P# (RDU=M-MSW, F-FSW, P-PSIG; RD=Numerical value).
- 5 Verify current sea level garment ensemble properties, collect new values, or re-initialize properties to the program assigned values. (See Function REINIT.)

[†]Numeric labels correspond to the question numbers (1-23) of Appendix D.

- 6 Verify current regional undergarment thicknesses (in CM), collect new multipliers, or re-initialize multipliers to the program assigned values. (See Function REINIT.)
- 7 Verify current allowable regional heat fluxes (W/M²), collect new value, or re-initialize heat fluxes to the program assigned values. (See Function REINIT.)
- 8 Verify current regional biasing factors (dimensionless), collect new values, or re-initialize biasing factors to the program assigned values. (See Function REINIT.)
- 9 Input where to write output file. (T-Screen, F-DMPDAT.LST)
- 10 Input number of finite difference nodes (NN).

IF REU=N GO TO 14

11 Determine if a comparison of predicted and experimental data is to be performed.
(QCOMP=Y-Perform comparison, N-No comparison)

IF OCOMP=N GO TO 14

- 12 Input total surface area of the experimental subject (TAR).
- 13 Input the name of the direct access file containing the experimental data. (See Appendix A.)

Open direct access data file specified in question 13.

IF QCOMP=Y GO TO 16

14 Input design mean skin temperature (TDMS).

15 Input ambient temperature (TA).

16 Determine region or regions for which to perform calculations (BR).

17 Determine the subject's posture.
(ATT=0-Sitting, 1-Standing, 2-Prone)

Do to Z for each region specified:

Open output file specified in question 9.

IF QCOMP=N GO TO C

Do to X for each experimental time:

Determine TDMS by using Hody's mean skin temperature, Equation 8 of Chapter IV, and TA from the experimental data.

C[†] IF BR≠1 or BR≠9 or (BR≠4 and ATT≠0) GO TO D (Note: BR=1 and BR=9 imply spheres and are treated as single node regions for all postures. BR=4 and ATT=0 indicate a horizontal cylinder, the thigh, while the subject is sitting. For this case the thigh is treated as a single node region.)

SET J=1

GO TO E

D Do to W J=1 to number of nodes (NN):

E Calculate the nodal overall heat transfer coefficient for the garment ensemble (See function subroutine OHTC.) by:

U = OHTC(J)

IF REU = Y GO TO F

Note: REU = S indicates the research mode with corrected U's,

REU = Y indicates the research mode with uncorrected U's,

REU = N indicates the production mode which always corrects U's.

[†]Alphabetic symbols are used to label all statements except for those which correspond to the questions (1-23) of Appendix D.

$$U = U * BF(BR)$$

BF(BR) = Array containing the empirically
derived baising factors.
(See Chapter VII.)

F Sum nodal U values and increment occurrence counter by:

$$US = US + U$$

UN = UN + 1.0

Calculate the predicted rate of heat loss per unit of nodal surface area (W/M^2) by:

$$QR = U(T1 - TA)$$

T1 = predicted regional skin temperature.

Add the rate of heat loss (watts) from this node to the nodal rate of heat loss sum by:

$$Q(BR) = Q(BR) + (QR * SAM(BR)/NN)$$

Q(BR) = Variable containing running sum for region BR,

SAM = Array containing the regional surface areas of the 9 body regions
(Fig. 1 of Chapter I),

SAM(BR) = Variable containing surface area of region BR,

NN = Number of nodes per region
(question 10).

If BR=1 or BR=9 or (BR=4 and ATT=0) GO TO G

W Continue - to next node.

G Determine regional heat flux (W/M^2) by:

$$Q(BR) = \frac{Q(BR)}{SAM(BR)}$$

Determine regional overall heat transfer coefficient by:

$$U = US/UN$$

Determine regional allowable rate of heat loss (watts) by:

$$QA(BR) = QALL(BR) * SAM(BR)$$

QALL(BR) = Variable containing allowable heat flux (W/M^2) for region BR.

Determine regional predicted heat loss (watts) by:

$$QP(BR) = Q(BR) * SAM(BR)$$

Determine required regional supplementary rate of heat loss (watts) by:

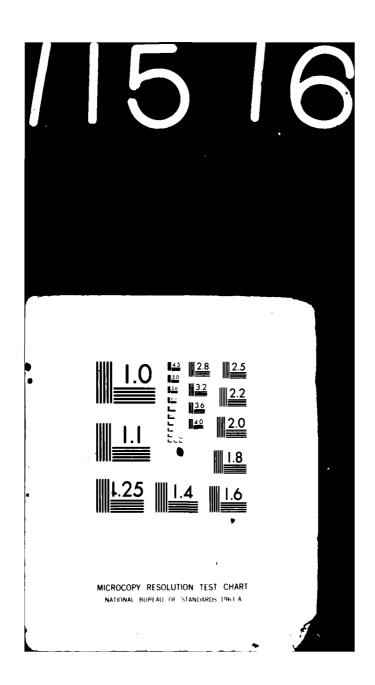
$$QSUPP(BR) = QP(BR) - QA(BR)$$

Determine required regional supplementary heat flux (W/M^2) by:

$$QSUP = Q(BR) - QALL(BR)$$

IF QCOMP=N GO TO X

DUKE UNIV MEDICAL CENTER DURHAM N C F 8 MALL LAB FOR-ETC F/8 6/17 THE DEVELOPMENT OF PREDICTIVE ENSINEERING FORMULATIONS FOR DIVER-ETC(U) 1982 C E JOHNSON J D COLLINS NO0014-79-C-0379 AD-A115 167 UNCLASSIFIED



Fill appropriate portions of array P for this experimental time with the regional predicted skin temperature (T1), heat flux (Q(BR)), and overall heat transfer coefficient averaged across all nodes (U), also the design mean skin (TDMS) and ambient (TA) temperatures. Array P is used to preserve values for the possibility of later plotting.

The layout of the plotting array P is as described below.

P(I,1) = Experimental time

P(I,2) = Experimental temperature (TEXPT)

P(I,3) = Predicted temperature (T1)

P(I,4) = Experimental heat flux (QEXPT)

P(I,5) = Predicted heat flux (O(BR))

P(I,6) = Experimental overall heat transfer coefficient (UEXPT)

P(I,7) = Predicted overall heat transfer coefficient (U)

P(I,8) = Design mean skin temperature (TDMS)

P(I,9) = Ambient temperature (TA)

Susbcript I is incremented by one each time a new time record \dot{f} is processed (i.e., I=1 indicates time = 0.0, I=2 indicates time = 3.0, I=3 indicates time = 6.0; assuming a time increment of 3.0 minutes).

Initialize summing variables as zero:

TEXPT = 0.0

SWGT = 0.0

QEXPT = 0.0

SWGTQ = 0.0

UEXPT = 0.0

SWGTU = 0.0

^{*}See Foreword for the connotation of time record.

Do to J L=1,2:

SET M=COR(BR,L)

COR = The array containing the correspondence between the 9 region[†] model man and the 12 segment^{††} Hody man. Each row of array COR corresponds to a body region of the model man.

For BR=3, the abdomen, COR(3,1) = 3-Hody's abdomen, COR(3,2) = 5-Hody's lower back.

For BR=6, the feet, COR(6,1) = 12-Hody's feet, COR(6,2) = -1.

The -1 indicates that the correspondence is one to one.

IF M=-1 GO TO J

IF EXP(M+13)=0 GO TO H

EXP(M+13) = Experimental temperature for Hody segment M.

Add weighted temperature for segment M into regional sum and increment occurrence counter by:

TEXPT = TEXPT + (EXP(M+13) * WGT(M))

SWGT = SWGT + WGT(M)

WGT(M) = Variable containing the Hody surface area fraction for Hody segment M.

[†]All references to a region indicate one of the 9 regions of the developed model man (Fig. 1 of Chapter I).

^{††}All references to a segment indicate one of the 12 segments used to record the experimental data (Fig. 2 of Chapter I).

Н

IF
$$EXP(M+1)=0$$
 GO TO I

EXP(M+1) = Experimental rate of heat loss
for Hody segment M.

Add rate of heat loss for segment M into regional sum and increment occurrence counter by:

$$QEXPT = QEXPT + EXP(M+1)$$

 $SWGTQ = SWGTQ + WGT(M)$

I IF EXP(M+1)=0 OR EXP(M+13)=0 GO TO J

Add overall heat transfer coefficient term into regional sum and increment occurrence counter by:

UEXPT = UEXPT +
$$\left(\frac{\text{EXP}(M+1)}{\text{EXP}(M+13)} - \text{TA}\right)$$

SWGTU = SWGTU + WGT(M)

J Continue - to next value of L.

IF SWGT=0 GO TO K

$$TEXPT = \frac{TEXPT}{SWGT}$$

K IF SWGTQ=0 GO TO M

 $QEXPT = \frac{QEXPT}{SWGTQ * TAR}$

IF SWGTU=0 GO TO N

$$UEXPT = \left(\frac{UEXPT}{SWGTU * TAR} \right)$$

N Fill the appropriate portions of array P for this experimental time (P(I,1)) with the regional experimental skin temperature (TEXPT in P(I,2)), surface heat flux (QEXPT in P(I,4)), and overall heat transfer coefficient (UEXPT in P(I,6)) for possible later plotting. (See the previous description of array P for details.)

X Continue - to next experimental time.

IF OCOMP=N GO TO Z

18 Determine if plots comparing dimensional experimental and predicted skin temperatures, heat fluxes, or overall heat transfer coefficients are desired.

(PLD= Y-Produce plots, N-No plots)

IF PLD=N GO TO 21

- 19 Verify assumed y-axis scale factors for the three different dimensional plots or enter new values.
- 20 Verify assumed x-axis scale factors (one set of scale factors for all three dimensional plots) or enter new values.

Produce three dimensional plots comparing predicted and experimental values of regional skin temperature, heat flux, and overall heat transfer coefficient with the scales defined in questions 19 and 20.

- 21 Determine if plots comparing dimensionless predicted and experimental values of regional normalized skin temperature and Biot number are desired.

 (PLN=Y-Produce plots, N-No plots)
- 22 Verify assumed y-axis scale factors for both of the non-dimensional plots or enter new values.
- 23 Verify assumed x-axis scale factors (one set of scale factors for both dimensionless plots) or enter new values.

Produce two dimensionless plots comparing predicted and experimental values of regional normalized skin temperature and Biot number using the scales defined in questions 22 and 23.

Z Close output file specified in question 9.

Continue

GO TO 1

STOP

Function REINIT(I)

Declare values passed to subroutine.

Define default values for the sea level garment ensemble properties (I=1), regional undergarment thicknesses (I=2), allowable regional heat fluxes (I=3), and the regional biasing factors (I=4).

IF I=1 GO TO A IF I=2 GO TO B IF I=3 GO TO C IF I=4 GO TO D

RETURN

A Push assumed default values of the sea level garment ensemble properties into the appropriate variables which destroys their current contents.

RETURN

B Push assumed default values of the regional undergarment multipliers into the appropriate array variable which destroys their current contents.

RETURN

C Push assumed default values of the allowable regional heat fluxes into the appropriate array variables which destroys their current contents.

RETURN

D Push assumed default values of the regional biasing factors into the appropriate array variables which destroys their current contents.

RETURN

Declare variables passed to subroutine.

Calculate depth of regional datum below shoulder level (RDS), depth of start of nodal element below the regional datum (SEP), and the depth of the mid-point of the nodal element below the shoulder reference (RED).

Calculate decimal percent change in undergarment thickness due to the hydrostataic pressure of RED centimeters of seawater (CSW) at the mid-point of the nodal element (DPCT).

Calculate suit entrapped gas temperature (MT). Estimate (MT) by averaging regional skin and ambient temperatures.

Calculate thermal conductivity ratio (CR) of air at sea level and the entrapped gas at depth. See function TC.

Calculate specific thermal resistance of undergarment at depth due to change in thermal conductivity of entrapped gas (SRUGA) by:

SRUGA = SRO * CR

SRO = Specific thermal resistance (CLO/CM) of undergarment at sea level.

Correct undergarment specific thermal resistance (SRUGA) for effects of hydrostatic suit squeeze (SRUGHA) at a depth of RED (CSW) below the shoulder reference by:

SRUGHA = SRUGA (1 - (DR * DPCT))

DR = decimal percent change in specific thermal resistance at sea level per decimal percent change in undergarment thickness. (See Chapter V.)

Convert specific thermal resistance (SRUGHA) in CLO/CM to a thermal resistance in M^{2} °C/W (RUGHAJ).

Note: 1 CL0 = 0.18 M^2 -HR°C/KCAL or 1 CL0 = 0.155 M^2 °C/W

Calculate radius (R1 in meters) from center line of region to skin surface by region diameter divided by 2.

Calculate radius (R2 in meters) from region center line to undergarment/outer garment interface by:

R2 = R1 + (WUGO * TWUGO(BR) * (1 - DPCT))

WUGO = Unit undergarment thickness at sea level.

TWUGO = Array containing the regional multipliers indicating the number of layers of unit thickness material per region. Variable BR indicates region of interest.

Calculate radius (R3 in meters) from region center line to outer garment/outer boundary layer interface by R2 plus thickness of outer garment (assumed incompressible).

Calculate undergarment thermal resistance (RUG); corrected for curvature of region and biased to the skin surface area by:

$$RUG = \frac{R1 * RUGHAJ * 1n (R2/R1)}{R2 - R1}$$

(Note: In indicates the logarithm to the base e.)

Calculate resistance of outer garment corrected for curvature of region and biased to the skin surface area by:

$$ROG = \frac{R1 * 1n (R3/R2)}{COG}$$

COG = thermal conductivity of outer
garment.

Calculate regional temperature of outer garment/outer boundary layer interface (T3 in $^{\circ}$ C) by Secant Method with function subroutine F(T).

Calculate regional convective heat transfer coefficient for outer boundary layer (CHTC) (See function subroutine CHTC.) at temperature T3.

Calculate regional outer boundary layer resistance (ROBL) biased to the skin surface area by:

$$ROBL = \frac{R1}{R3 * CHTC * T3}$$

Calculate overall heat transfer coefficient of garment ensemble (OHTC) biased to skin surface area by:

$$OHTC = \frac{1.0}{RUG + ROG + ROBL}$$

Function F(T)

Note: This function is used by the Secant Method to evaluate if a new estimate (T3) of the temperature of the outer garment's outer surface is correct. If T3 is estimated correctly the value of F, below, will be approximately zero. T3 is the variable name used in the calling module. The call to this function appears as F(T3).

Declare passed variables.

Calculate by using the temperature of the outer garment/outer boundary layer interface (T), which is passed from subroutine OHTC, a value of the energy balance F by:

$$F = \frac{T1 - TA}{RUG + ROG + CHTC(T3,R3)} - \frac{T1 - T}{RUG + ROG}$$

T1 = Regional skin temperature passed from the calling module in common, RUG = Resistance of undergarment passed from calling module in common, ROG = Resistance of outer garment passed from calling module in common, CHTC(T3,R3) = Calls Function CHTC to determine convective heat transfer coefficient at radius R3 and temperature T3.

Function CHTC(T3,R3)

Declare passed variables.

Determine for the specified subject posture (ATT) whether the region is a vertical or horizontal cylinder, or a sphere.

If a vertical cylinder, set the characteristic length (CL in meters) to the length of the cylindrical region by:

CL = B(BR,3)

B(BR,3) = Variable containing length of region BR.

GO TO A

If a horizontal cylinder set the characteristic length (CL in meters) to the diameter of the cylindrical region by:

CL = 2.0 * R3

R3 = Radius to outer surface of the garment ensemble.

GO TO A

If a sphere, set the characteristic length (CL in meters) to the diameter of the spherical region by:

A Grashof/Prandtl number product routine:

Calculate film temperature (TF in °C) by:

$$TF = \frac{T3 + TA}{2 \cdot 0}$$

T3 = Temperature of outer garment/outer boundary layer interface passed from Function OHTC.

TA = Ambient temperature passed from Main program.

Calculate a value for property grouping

ALPHA (
$$\frac{g\beta\rho^2C_p}{uk}$$
) for water by:

log (ALPHA) =
$$9.80714 (log (TF))^{0.12733}$$

ALPHA = $10^{log} (ALPHA)$

(Equation fits tabularized data for water over temperature range of 4.44 to 21.11 °C, taken from Holman [40].)

Note: Our FORTRAN will not exponentiate a negative number to a non-interger power, thus TF must be > 1.0 since log of a number less than 1.0 is negative.

Calculate Grashof/Prandtl number product (GRPR) by:

GRPR = ALPHA
$$\star$$
 CL³ \star (T3 - TA)

T3 = Outside surface temperature, TA = Ambient temperature. Branch to equations for determination of Nusselt number for a vertical or horizontal cylinder, or sphere. The development of these empirical equations can be found in Chapter V.

If vertical cylinder, by:

 $log (NU) = 9.1934 - 2.4128 (log (GRPR)) + 0.1817 (log (GRPR))^2$

GO TO B

If horizontal cylinder, by:

log(Nu) = 0.2486(log(GRPR)) - 0.4483

GO TO B

If sphere, by:

log(NU) = 0.46486(log(GRPR)) - 1.9726

B Computing CHTC from log (NU):

Calculate thermal conductivity of water boundary layer (CF in W/M°C) by:

 $CF = 0.56662 + 1.7977 \times 10^{-3} * TF$

(Equation fits tabularized data for water over temperature range of 0 to 21.11 °C, taken from Holman [40].)

Calculate convective heat transfer coefficient CHTC by:

$$CHTC = \frac{CF * 10^{\log (Nu)}}{CL}$$

Function TR(TDMS,BR)

This subroutine calculates the regional (Fig. 1 of Chapter I) experimental skin temperature from the experimental data recorded from Hody's 12 segments (Fig. 2 of Chapter I).

Declare passed variables.

Initialize summation variables TR and SWGT to zero.

Do to A L=1,2:

SET J=COR(BR,L)

COR = The array containing the correspondence between the 9 region model man (Fig. 1 of Chapter I) and the 12 segment Hody man (Fig. 2 of Chapter I). Each row of array COR corresponds to a body region of the model man.

For BR=3, the abdomen, COR(3,1) = 3-Hody's abdomen, COR(3,2) = 5-Hody's lower back.

For BR=6, the feet, COR(6,1) = 12-Hody's feet, COR(6,2) = -1.

The -1 indicates that the correspondence is one to one.

IF J=-1 GO TO A

Add weighted predicted temperature for segment J into regional sum and increment occurrence counter by:

$$TR = TR + PRED(J,TDMS) * WGT(J)$$

 $SWGT = SWGT + WGT(J)$

PRED = Function subroutine for determining predicted skin temperature for any of Hody's 12 segments, (See Function PRED(REG,TDMS) for details.) WGT = Array containing surface area fractions for Hody's 12 segments.

A Continue - to next L value.

Determine weighted average TR by:

$$TR = \frac{TR}{SWGT}$$

Function PRED(REG, TSKM)

This function calculates a value for one of Hody's 12 segments by using an empirically verified Kerslake type model. This function is called by Function TR.

Declare passed variables.

Calculate the predicted temperature for the segment specified in REG by:

PRED = TSKM + (KA(REG) * KR)

TSKM = Design mean skin temperature,
KA(REG) = Coefficient for the Hody segment
specified by REG,
KR = Constant used in the temperature
prediction equations developed to
predict the skin temperatures at the 12
Hody segments.

The KA(REG) and KR values were derived from linearized experimental data taken from 4 resting subjects in helium oxygen at 20 °C and 200 MSW. The equation for PRED is based on a Kerslake type model. The development of this equation is found in Chapter IV.

Function TC(TDC,Z)

Computes the thermal conductivity of air (TC) at a temperature of TDC °C and a pressure of Z MSW from a table of data extracted from the U.S. Navy Diving Gas Manual [42]. A method of two-dimensional linear interpolation described by Carnahan, Luther, and Wilkes, Applied Numerical Methods, p. 63 [49] is used. The table of air data covers a temperature range of -1.11 to 54.44 °C and a pressure range of 14.7 to 200.0 PSIA.

Subroutine PLOTD(IR, PSYM, BR)

This subroutine must be called three different times to generate the three graphs of temperature, heat flux, and conductance.

Declare variables passed to subroutine.

The array P as filled in the Main program is passed to this subroutine via a common block statement. Each row corresponds to a specific time. For the Kth row the array is filled as follows.

P(K,1) = Experimental time
P(K,2) = Experimental temperature (TEXPT)
P(K,3) = Predicted temperature (T1)
P(K,4) = Experimental heat flux (QEXPT)
P(K,5) = Predicted heat flux (Q(BR))
P(K,6) = Experimental overall heat
transfer coefficient (UEXPT)
P(K,7) = Predicted overall heat transfer
coefficient (U)
P(K,8) = Design mean skin temperature
(TDMS)
P(K,9) = Ambient temperature (TA)

The passed variable IR indicates the offset into array P at which to find the experimental and predicted pairs of temperatures, heat fluxes, and overall heat transfer coefficients.

Call subroutine SYMBOL to write body region name on plot. (The subroutines SYMBOL, PLOT, LINE, and others used in this subprogram, which are not outlined in this flow chart, are specialized plotting subroutines detailed in reference 50.)

Call subroutine PLOT to reset plot pointer to origin.

Do to Z J=1,2: (J=1-Experimental curve generated, 2-Predicted curve generated)

Do to Y K=1,NREC:

Fill the array XP with the experimental times to be plotted (Skip times where the data is less than or equal to zero.) by:

$$XP(K) = P(K,1)$$

Fill the array YP with the dimensional experimental (J=1) or predicted (J=2) data of regional skin temperature (IR=1), heat flux (IR=3), or overall heat transfer coefficient (IR=5) depending on the current values of the variables J and IR by:

$$YP(K) = P(K,IR+J)$$

Y Continue - to next time record.

IF J≠1 GO TO A

Write output file containing both experimental and predicted data points plotted. (Since both the experimental and predicted values are already in array P, they are both printed at once.)

A Call subroutine LINE to write curve defined by the ordered pairs contained in XP and YP with the plotting symbol defined in PSYM(J).

Call subroutine SYMBOL to write curve label (i.e., T-EXPT or T-PRED, Q-EXPT or Q-PRED, U-EXPT or U-PRED) contained in array variable LABEL(J) passed in common from the Main program.

Call subroutine SYMBOL to write curve plotting symbol (i.e., '+' - experimental, 'x' - predicted) defined in PSYM(J).

Z Continue to next curve.

This subroutine must be called two different times to generate the two graphs of normalized temperature and Biot number.

Declare variables passed to subroutine.

The array P as filled in the Main program is passed to this subroutine via a common block statement. Each row corresponds to a specific time. For the Kth row the array is filled as follows.

P(K,1) = Experimental time

P(K,2) = Experimental temperature (TEXPT)

P(K,3) = Predicted temperature (T1)

P(K,4) = Experimental heat flux (QEXPT)

P(K,5) = Predicted heat flux (Q(BR))

P(K,6) = Experimental overall heat transfer coefficient (UEXPT)

P(K,7) = Predicted overall heat transfer

coefficient (U)

P(K,8) = Design mean skin temperature

(TDMS)

P(K,9) = Ambient temperature (TA)

The passed variable IR indicates the offset into array P at which to find the experimental and predicted pairs of temperatures, heat fluxes, and overall heat transfer coefficients.

Call subroutine SYMBOL to write body region name on plot. (The subroutines SYMBOL, PLOT, LINE, and others used in this subprogram, which are not outlined in this flow chart, are specialized plotting subroutines detailed in reference 50.)

Call subroutine PLOT to reset plot pointer to origin.

Determine depth of the mid-point of the region BR below sea level (RMD) by taking into account the posture of the subject. This depth is used to calculate the thermal conductivity of air for use in the Biot number computations.

Do to Z J=1,2: (J=1-Experimental curve generated, 2-Predicted curve generated)

Do to Y K=1,NREC:

Fill the array XP with the experimental times to be plotted (Skip times where the data is less than or equal to zero.) by:

$$XP(K) = PD(K,1) = P(K,1)$$

Calculate and fill array YP with the dimensionless experimental (J=1) or predicted (J=2) data of regional normalized skin temperature (IR=1) or Biot number (IR=5), depending on the current values of the variables J and IR. Use the following equations to determine the normalized skin temperature and Biot number.

Calculate the regional normalized skin temperature (TN) by:

$$YP(K) = PD(K,J+1) = \frac{P(K,IR+J) - P(K,9)}{P(K,8) - P(K,9)}$$

P(K,IR+J) = Experimental (J=1) or
predicted (J=2) regional skin temperature,
P(K,9) = Experimental ambient temperature,
P(K,8) = Hody mean skin temperature
determined from the 12 experimental
temperatures,
IR = 1.

Calculate the raional Biot numbers (BI) by:

$$YP(K) = PD(K,J+1) = \frac{P(K,IR+J) * (B(BR,2)/2.0)}{TC(TM,RMD)}$$

P(K,IR+J) = Experimental (J=1) or predicted (J=2) overall heat transfer coefficient for region BR,
TC(TM,RMD) = Estimate of thermal conductivity of the suit entrapped gas.
Estimate is based on a mean entrapped gas temperature (TM) at a depth equivalent to the mid-point of the region (RMD),
TM = The average of the regional predicted skin (T1) and the ambient (TA) temperatures,
RDM = Depth of the mid-point of the region below sea level,
B(BR,2) = Diameter of region BR,
IR = 5.

Y Continue - to next time record.

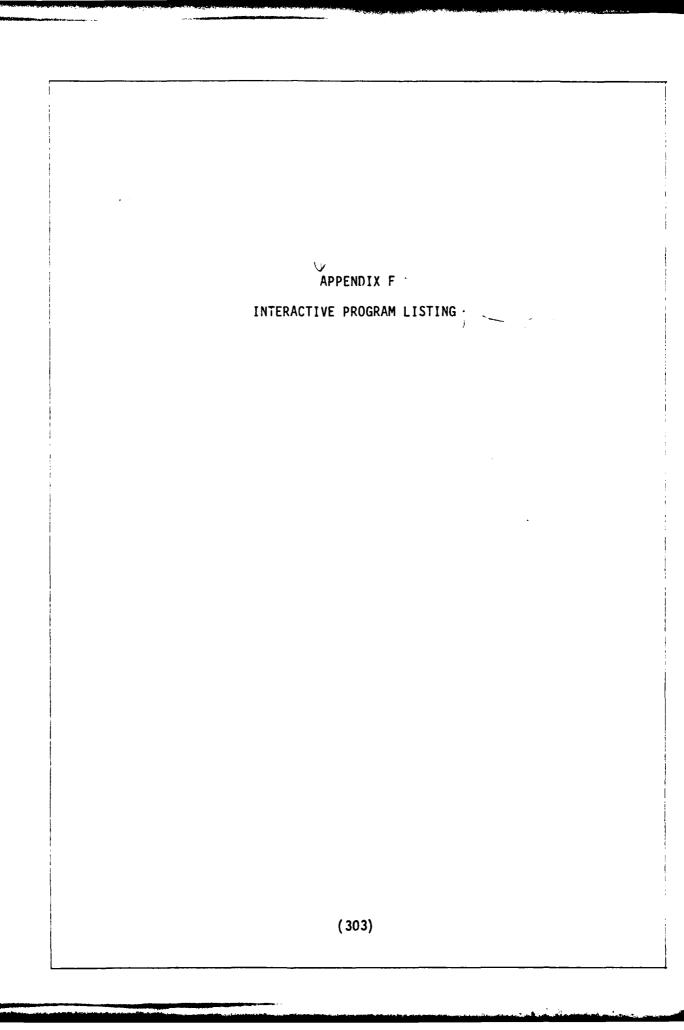
Call subroutine LINE to write curve defined by the ordered pairs contained in XP and YP with the plotting symbol defined in PSYM(J).

Call subroutine SYMBOL to write curve label (i.e., TN-EXPT or TN-PRED, BI-EXPT or BI-PRED) contained in array variable LABEL(J) passed in common from the Main program.

Call subroutine SYMBOL to write curve plotting symbol (i.e., '+' - experimental, 'x' - predicted) defined in PSYM(J).

Z Continue - to next curve.

Write output file containing both experimental and predicted data points plotted. Both loops of Z must be completed since only then will both the experimental and predicted values be available. (Array PD is used to store the experimental and predicted values.)



```
REAL KA, KR, COG, G(10), EXP(29), SCALY(3, 3), SCALYN(2, 3)
       1, LX, SX, IX, LY, SY, IY, LYS, XP(125), YP(125)
       2,BF(9),QA(9),QP(9),QSUPP(9),SAM(9),QALL(9)
       REAL*8 LABEL(3), BREG(10)
        INTEGER FLAG1, FLAG2, COR, BR, ATT, SYM(2)
       BYTE RDU, GCOMP, FILE (30), WG, PLD, PLN, DUM, REU, NST
        1, PRTL(11), PRT, OUT, PU(2)
       COMMON /PREDD/KA(12), KR
        1,/BODY/B(9,3),COR(9,2),WGT(12)
       2,/TRNOSQ/C(6,7)
       3, /SUIT/WUGO, DR, SRO, WDG, CDG, TWUGO (9)
        4, /DEBUG/FLAG2, LO
        5,/OHTCD/RUGHA, RUG, ROG, ROBL, R1, R2, R3, T1, T3, FLAG1
       6, Q1A, Q13
        7, /PROB/BR, ATT, RD, RDM, TA, NN, TDMS, DZ, DZV, FLAG3, RDS
       8. RDU
        9, /PLOT/P(125, 9), LX, SX, IX, LY, SY, IY, LYS, LABEL, NREC
        1, BREG, XP, YP, PD(125, 3), LCL, CH, REU, PRT(13)
        2,/MISC/QALL,BF
      NOTE: ALL VALUES FOR ARRAYS ENTERED VIA DATA STATEMENTS
            ARE ENTERED IN COLUMN MAJOR ORDER!!
C
        ARRAY B - CONTAINS REGIONAL BODY DIMENSIONS
                  *NOTE* ALL VALUES ARE IN METERS
                - 1ST COLUMN CONTAINS IDENTIFICATION OF SHAPE
                      -1 IMPLIES SPHERE
                       O IMPLIES CYLINDER
                      +# IMPLIES CONIC = DIAMETER OF TOP OF CONE
                  2ND # IS DIAMETER OF SPHERE, CYLINDER OR
                      BOTTOM OF CONE
                  3RD # IS THE HEIGHT OF REGION
        !DIMENSIONAL NUMBERS ENTERED FOR MODEL MAN
        !#NOTE# ALL CYLINDERS AND CONES ARE CONNECTED END
                TO END.
                ID# - REGION = SHAPE / ENTERED #'S /
                1 - \text{HEAD} = \text{SPHERE} / -1.0, 0.206, 0.206 /
                2 - TORSO = CYLINDER / 0.0,0.30,0.353 /
                3 - ABDOMEN = CYLINDER / 0.0,0,30,0,353 /
                4 - THIGH = CYLINDER / 0.0, 0.15, 0.383 /
                5 - CALF = CYLINDER / 0.0, 0.12, 0.328 /
                  - FOOT = CYLINDER / 0.0,0.15,0.104 /
                7 - UPPER ARM = CYLINDER / 0.0,0.096,0.223 /
                8 - LOWER ARM = CYLINDER / 0.0,0.07,0.267 /
                9 - HAND = SPHERE / -1.0.0.123.0.123 /
        ARRAY COR (9,2)
                         CONTAINS THE CORRESPONDENCE BETWEEN
                OUR 9 REGION MODEL ID #'S AND THE 12 SEGMENT
                HODY/ZUMRICK MEASUREMENT SYSTEM ID #'S.
                THE ROW NUMBERS OF THE ARRAY CORRESPOND TO THE
```

```
BODY REGION ID'S FOR OUR 9 REGION MAN.
!FOR EXAMPLE: 9 REGION MODEL, REGION TORSO(2)
!CORRESPONDS TO THE 12 SEGMENT MODEL, SEGMENTS
!CHEST(2) AND UPPER BACK (4).
!ROW#
         9 REGION
                           12 SEGMENT MODEL
        MODEL NAME
                           CORRESPONDING SEGMENTS NAME(ID#)
                           ID #'S ARE IN ARRAY COR(9,2)
! 1
        HEAD
                           HEAD(1),(-1)
                           CHEST(2), UPPER BACK(4)
! 2
        TORSO
!3
        ABDOMEN
                           ABDOMEN(3), LOWER BACK(5)
! 4
        THIGH
                           FRONT THIGH(8), REAR THIGH(10)
15
        CALF
                           FRONT CALF(9), REAR CALF(11)
! 6
        FOOT
                           FOOT(12), (-1)
!7
        UPPER ARM
                           ARM(6),(-1)
!8
        LOWER ARM
                           ARM(6), (-1)
19
        HAND
                           WRIST(7), (-1)
                           NOTE (-1) INDICATES THAT ONLY
                           ONE CORRESPONDING SEGMENT IS
                           AVAILABLE FROM 12 SEGMENT MODEL
ARRAY SAM(9) CONTAINS THE REGIONAL SURFACE AREAS OF OUR
!MODEL MAN IN METERS SQUARED (M**2)
DATA B/-1. 0, Q. 0, 0. 0, 0. 0, 0. 0, 0. 0, 0. 0, 0. 0, -1. 0
1, 0, 206, 0, 30, 0, 30, 0, 15, 0, 12, 0, 15, 0, 096, 0, 07, 0, 123
2, 0, 206, 0, 353, 0, 353, 0, 383, 0, 328, 0, 104, 0, 223, 0, 267, 0, 123/
3, CDR/1, 2, 3, 8, 9, 12, 6, 6, 7, -1, 4, 5, 10, 11, -1, -1, -1, -1/
4, SAM/O. 1333, O. 3327, O. 3327, Q. 3610, O. 2474, O. 1334
5, 0. 1490, 0. 1174, 0. 0950/
ARRAY C - CONTAINS THERMAL CONDUCTIVITY DATA FOR AIR
          AS F(TEMP, PRES)
         - PRESSURES - 14. 7, 30. 0, 50. 0, 100. 0 PSIA
         - TEMPERATURES - 30. 0, 50. 0, 70. 0, 90. 0, 110. 0,
                            130.0 F
         **NOTE**
           CONDUCTIVITIES HAVE UNITS BTU/SEC FT F
           AND VALUES MUST BE MULTIPLIED BY 1.0E-6
         DATA TAKEN FROM:
         - U.S. NAVY DIVING GAS MANUAL,
         - NAVSHIPS 0994-003-7010, 1971
         - PAGE T-4 (AIR DATA)
DATA C/0. 0, 14. 7, 30. 0, 50. 0, 100. 0, 200. 0
2, 30. 0, 3. 93, 3. 93, 3. 95, 3. 98, 4. 03
3, 50. 0, 4. 06, 4. 07, 4. 08, 4. 11, 4. 16
```

C

C

C

ARRAY KA CONTAINS CONSTANTS, A(i)'S, NEEDED FOR THE

4,70. 0, 4. 19, 4. 20, 4. 21, 4. 24, 4. 29 5,90. 0, 4. 32, 4. 33, 4. 34, 4. 37, 4. 42 6,110. 0, 4. 45, 4. 46, 4. 47, 4. 49, 4. 54 7,130. 0, 4. 58, 4. 59, 4. 59, 4. 62, 4. 66/

SEGMENTAL TEMPERATURE PREDICTIONS EQUATIONS. THESE !CONSTANTS WERE DERIVED FROM KERSLAKE'S MODEL. SEE !TEXT FOR DETAILS. C VARIABLE KR IS CONTANT R NEEDED FOR SEGMENTAL !TEMPERATURE PREDICTIONS. !THE KR CONSTANT WAS DERIVED FROM A KERSLAKE TYPE MODEL SEE TEXT FOR DETAILS OF DERIVATION DATA KA/0, 36, 0, 27, 0, 30, 0, 52, -0, 08, 0, 22, -0, 64, -0, 04, 1-0. 16, -0. 06, -0. 55, -0. 86/ 1, KR/2, 946/ C C ARRAY GALL (9) CONTAINS THE REGIONAL ALLOWABLE HEAT !FLUXES(W/M**2) ADAPTED FROM THE DATA OF BURRISS, !PRINCIPLE INVESTIGATOR, 'STUDY OF THE THERMAL PROCESSES !FOR MAN IN SPACE', NASA CONTRACT REPORT CR-216. C ARRAY BF(9) CONTAINS THE REGIONAL BIASING FACTORS USED !TO MAKE PREDICTED OVERALL HEAT TRANSFER COEFFICIENTS !AGREE MORE FAVORABLY WITH THE EXPERIMENTAL VALUES. PRED OHTC * BF(i) = CORRECTED PRED OHTC DATA GALL/23. 3, 60. 0, 49. 7, 42. 4, 85. 0, 97. 0, 98. 9, 125. 25 1, 265, 86/ 2, BF/2, 63, 2, 63, 2, 27, 3, 50, 3, 21, 12, 70, 2, 29, 2, 19, 3, 49/ C DEFINITION OF SUIT THERMAL PROPERTIES AND DIMENSIONS ! WUGO = WIDTH (THICKNESS) OF UNDER GARMENT AT SEA LEVEL (CM). = SPECIFIC RESISTANCE OF UNDER GARMENT !SRO AT SEA LEVEL (CLO/CM) = DECIMAL % CHANGE IN SRO PER DECIMAL % CHANGE ! DR IN UNDERGARMENT THICKNESS (CLD/CM/CLD/CM/CM/CM) (IE: DIMENSIONLESS) EXPERIMENTALLY DETERMINED. SEE TEXT FOR DETAILS. = WIDTH OF QUTER GARMENT (CM) => 1/16 INCH ! WOG - THERMAL CONDUCTIVITY OF OUTER GARMENT MATERIAL ! COG WATTS/M#C) = ARRAY CONTAINING THE # OF THICKNESSES OF C TWUCO UNDERGARMENT MATERIAL FOR EACH REGION. EACH LAYER IS 'WUGO' THICK. WGT - CONTAINS SURFACE AREA WEIGHTS FOR THE 12 SEGMENT C HODY MODEL. DATA WUGO, SRO, DR, WOG, COG/1. 63, 2. 27, 0. 1175, 0. 15875 1,0.17307/

```
2, TWUGO/1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 2, 0, 1, 0, 1, 0, 1, 0/
        3, WGT/0. 070, 0. 085, 0. 085, 0. 090, 0. 090, 0. 140, 0. 050, 0. 095
        4, 0, 065, 0, 095, 0, 065, 0, 070/
C
С
        BREG - ARRAY CONTAIN BODY REGION NAMES FOR PRINT
                ORDERED ACCORDING TO REGION ID #
        DATA BREG/'HEAD', 'TORSO', 'ABDOMEN', 'THIGH', 'CALF',
        1'FOOT', 'UP ARM', 'LOW ARM', 'HAND', 'TIME'/
C****************
        PLOTTING AND COMPARISON VARIABLES
               = ARRAY CONTAINS Y AXIS SCALES FOR T, Q, AND U
                  PLOTS
         CONTENTS OF ARRAY SCALY(3,3)
                          2
        !COLUMN/! 1
        ! ROW
        ! 1
                ! 5. 0
                        20.0
                                 4. 0
                                         TEMPERATURES
                                 50.0
        !2
                ! 5. 0
                         0. 0
                                        HEAT FLUXES
        :3
                ! 4. 0
                         0. 0
                                 4.0
                                         TRANSFER COEF.
        !COLUMN 1 CONTAINS LENGTH OF Y-AXIS
        !COLUMN 2 CONTAINS STARTING Y-AXIS VALUE
        !COLUMN 3 CONTAINS Y-AXIS INCREMENT
                (IE: Y-AXIS UNITS/INCH(CM) )
        !SCALYN = ARRAY CONTAINS Y AXIS SCALES FOR
                  NORMALIZED TEMPERATURE AND BIOT # PLOTS
        ! CONTENTS OF ARRAY SCALYN(2,3)
        !COLUMN/! 1
                         2
                                  3
        ! ROW
                 ! 4. 0
        ! 1
                         0. 5
                                 0. 25
                                         NORMALIZED TEMPERATURES
        !2
                 ! 4. 0
                         0.0
                                 10.0
                                         BIOT NUMBERS
        !COLUMN 1 CONTAINS LENGTH OF Y-AXIS
        !COLUMN 2 CONTAINS STARTING Y-AXIS VALUE
        !COLUMN 3 CONTAINS Y-AXIS INCREMENT
                 (IE: Y-AXIS UNITS/INCH(CM) )
                = LENGTH OF X-AXIS
        !LX
                = STARTING VALUE FOR X-AXIS
        !SX
                = INCREMENT FOR X-AXIS
        ! IX
        !LY
                 = LENGTH OF Y-AXIS
        !SY
                = STARTING VALUE FOR Y-AXIS
        ! IY
                = INCREMENT FOR Y-AXIS
        !LYS
                = LENGTH Y-AXIS SAVED
        ! XP
                = ARRAY FOR X-AXIS VALUES FOR PLOTTING
        ! YP
                 = ARRAY FOR Y-AXIS VALUES FOR PLOTTING
        !LABEL = ARRAY FOR LEGEND NAMES FOR PLOTS
                 = ARRAY FOR SAVING X AND Y VALUES FOR PLOTTING
        !FILE
                 = ARRAY FOR NAME OF FILE CONTAINING EXPERIMENTAL
                   DATA FOR COMPARISON
                 = TOTAL AREA OF EXPERIMENTAL SUBJECT
        ! TAR
```

```
= SUM OF EXPERIMENTAL Q'S FOR SIMPLE SUM
        = SUM OF EXPERIMENTAL U'S
!UEXPT
        = SUM OF EXPERIMENTAL T'S
! TEXPT
! PLD
        = INDICATES WHETHER DIMENSIONAL PLOTS
          ARE WANTED OR NOT
!PLN
        = INDICATES WHETHER NON-DIMENSIONAL PLOTS
          ARE WANTED OR NOT
! IR
        = 0,4,6. O= NO LINEARIZED EXPT. PLOTS
                 4= PLOT LINEARIZED EXPT. G'S
                 6= PLOT LINEARIZED EXPT. U'S
! SWGT
         SUM OF HODY WEIGHTS FOR CONVERSION
          FROM HODY'S 12 SEGMENTS TO THE MODEL'S 9
          REGION FORM.
        = SUM OF HODY WEIGHTS FOR CONVERSION
! SWGTT
          OF SEGMENTAL EXPERIMENTAL TEMPERATURES
          FROM HODY'S 12 SEGMENTS TO THE MODEL'S 9
          REGION FORM.
SWGTQ
        = SUM OF HODY WEIGHTS FOR CONVERSION
          OF SEGMENTAL EXPERIMENTAL HEAT FLOWS
          FROM HODY'S 12 SEGMENTS TO THE MODEL'S 9
          REGION FORM.
! SWGTU
        = SUM OF HODY WEIGHTS FOR CONVERSION
          OF SEGMENTAL EXPERIMENTAL OVERALL HEAT
          TRANSFER COEFFICIENTS
          FROM HODY'S 12 SEGMENTS TO THE MODEL'S 9
          REGION FORM.
!LFN
        = LENGTH OF EXPT. FILE NAME. (NO. OF CHARACTERS)
!TS
        = TIME START FOR LINEARIZATION
!TE
        = TIME END FOR LINEARIZATION
! NREC
        = NUMBER OF EXPT. RECORDS (TIMES) AVAILABLE FOR
          COMPARISON
! GCDMP
        = Y OR N, INDICATES DESIRE FOR COMPARISON OF
          EXPERIMENTAL VALUE WITH PREDICTIONS.
!EXP IS THE ARRAY USED TO READ IN EXPERIMENTAL DATA
!VALUES FOR COMPARISON
!ARRAY & CONTAINS THE 9 COMPUTED REGIONAL HEAT FLUXES
!ARRAY OP CONTAINS THE 9 COMPUTED REGIONAL HEAT FLOWS
!ARRAY GA CONTAINS THE 9 ASSUMED REGIONAL ALLOWABLE
!HEAT FLOWS
!ARRAY GSUPP CONTAINS THE 9 COMPUTED REQUIRED
!REGIONAL HEAT FLOWS
ARRAY SCALY IS ENTERED INTO THE COMPUTER VIA A DATA
!STATEMENT IN COLUMN MAJOR ORDER AS:
 LYT, LYG, LYU, SYT, SYG, SYU, IYT, IYG, IYU
        WHERE: LYX >> LENGTH OF Y-AXIS
               SYX >> STARTING VALUE FOR Y-AXIS
               IYX => INCREMENTING VALUE FOR Y-AXIS
```

U'S)

(X IN THE ABOVE IMPLIES T'S, Q'S, OR

! QEXPT

```
ARRAY SCALN IS ENTERED INTO THE COMPUTER VIA A DATA
        ISTATEMENT IN COLUMN MAJOR ORDER AS:
        ! LYTN, LYBI, SYTN, SYBI, IYTN, IYBN
                WHERE: LYXX => LENGTH OF Y-AXIS
                       SYXX => STARTING VALUE FOR Y-AXIS
                       IYXX => INCREMENTING VALUE FOR Y-AXIS
                       (XX IN THE ABOVE IMPLIES TN'S OR BI'S)
        VARIABLES LX, SX, IX ARE ENTERED INTO THE PROGRAM VIA
        !A DATA STATEMENT AS:
        ! LX, SX, IX
                WHERE: LX => LENGTH OF X-AXIS
                       SX => STARTING VALUE FOR X-AXIS
                       IX => INCREMENTING VALUE FOR X-AXIS
        SYM IS A VECTOR CONTAINING THE INTEGERS CORRESPONDING
        ITO THE SYMBOLS TO BE USED FOR THE EXPERIMENTAL AND
        !PREDICTED VALUES RESPECTIVILY.
        DATA SCALY/5. 0, 5. 0, 4. 0, 20. 0, 0. 0, 0. 0, 4. 0, 50. 0, 4. 0/
        1, SCALYN/4. 0, 4. 0, 0. 5, 0. 0, 0. 25, 10. 0/
        2, LX, SX, IX/7. 0, 0. 0, 20. 0/
        3, SYM/3, 4/
        THE FOLLOWING VARIABLES ARE USED AS TEMPORARY VARIABLES
        ! AND HAVE NO PERMANENT MEANING
        !DUM, I, J, L, M, N
C*********************************
        !THIS SYSTEM LEVEL SUBROUTINE CALL IS USED TO ATTACH THE
        !TERMINAL TO THIS TASK.
                                 THIS PREVENTS RETURNS USED TO
        !TERMINATE RESPONSES FROM BEING INTERPRETED BY THE
        OPERATING SYSTEMS MONITOR CONTROL ROUTINE.
        CALL WTGID ("1420,"5)
                VARIABLES DEFINED IN MODULE MAIN
C MAIN
                = DEBUG PRINT FLAG (-1=>YES, Q=>NO)
        !FLAG2
        ! BR
                = BODY REGION ID (0-9)
        !RD
                = REFERENCE DEPTH => DEPTH BELOW SEA LEVEL
                  OF SHOULDER LINE (FSW, MSW, PSI)
                = INDICATOR OF UNITS OF
        ! RDU
                  (F=FSW, M=MSW, P=PSI)
        ! NN
                = # OF NODE TO DIVIDE EACH REGION INTO
                  FOR FINITE DIFFERENCE CALCULATIONS
        TUO!
                - VARIABLE CONTAINING DESIRED LOCATION
                  FOR OUTPUT PRINTS (T=TERMINAL,
                  F=DR: DMPDAT. LST)
                = TEMPERATURE - MEAN SKIN - AT WHICH TO PERFORM
        ! TDMS
                  CALCULATIONS (DESIGN MEAN SKIN TEMPERATURE)
        !TA
                = TEMPERATURE - AMBIENT - AT WHICH TO PERFORM
                  CALCULATIONS
                = TEMPERATURE OF THE SKIN SURFACE
        ! T1
                - ATTITUDE OF SUBJECT (DIVER)
        !ATT
```

```
(O=SITTING, 1=STANDING, 2=LAY HORTIZONTAL)
        ! ITOT
                = FLAG VARIABLE INDICATING WHETHER OR NOT
                  DOING ALL REGIONS OR A SINGLE REGION
                   ( -1=>ALL REGIONS, O=>SINGLE REGION)
        ! LO
                = VARIABLE CONTAINING LOGICAL UNIT #
                  AT WHICH TO PRINT OUTPUT PRINTS
                   (5=>TERMINAL, 3=>DR: DMPDAT, LST)
        !U
                = VARIABLE CONTAINING RESULTS OF CALCULATION
                  OF OVERALL HEAT TRANSFER COEFFICIENT
                  FOR SPECIFIED NODE OF SELECTED REGION
        !US
                = VARIABLE CONTAINING RUNNING SUM OF NODAL
                  U'S
        ! UN
                = VARIABLE CONTAINING THE COUNT OF THE
                  NUMBER OF NODES IN THE SUM (US)
        ' GR
                = VARIABLE CONTAINING HEAT LOSS CALCULATED FOR
                  EACH NODE
        ! QSUP
                = REGUIRED SUPPLEMENTARY HEAT FLUX FOR
                   THE REGION OF INTEREST
        !THE FOLLOWING VARIABLE FOUND IN MODULE MAIN ARE
        !DEFINED IN OTHER MODULES (SUBROUTINES, FUNCTIONS)
        !DZ, DZV, FLAG1, ROBL, ROG, RUG, RUGHA, R1, R2, R3, T3
        !INTEGER VARIABLE 'IB' AND ARRAY 'PRTL' ARE BOTH USED
        IBY THE OUTPUT PRINTING ROUTINES.
        !THESE VARIABLES HAVE BEEN ASSIGNED TO ALLOW MORE
        !EFFICIENT USE OF THE FORTRAN CODE
        DATA PRTL/' ','C','O','R','R','E','C','T','E','D',' '/
        1, IB/'--'/
30
        WRITE (5,31)
31
        FORMAT ('$ARE YOU A RESEARCH USER ? (Y, N, X) ')
        THESE VARIABLE ARE BEING PRE-DEFINED FOR THE
C
        PRODUCTION MODE.
                          ALL OF THESE VARIABLE CAN BE
        DYNAMICALLY MODIFIED IN THE RESEARCH MODE.
        REU='N'
        BR=0
        FLAG2=0
        FLAG1=0
        IR=0
        NN=1
        OUT='T'
        GCOMP='N'
        READ (5,32) REU
32
        FORMAT (1A1)
        IF (REU. NE. 'Y'. AND. REU. NE. 'N'. AND. REU. NE. 'X')
        1 00 TO 30
        IF (REU. EQ. 'N') GO TO 44
        IF (REU. EQ. 'X') GO TO 15
        WRITE (5,39)
39
        FORMAT ('$DO YOU WISH TO CORRECT PREDICTED '
        1, '''U'' VALUES ? (Y/N) ')
        READ (5,32) DUM
```

```
IF (DUM. EQ. 'Y') REU='S'
40
        WRITE (5,41)
41
        FORMAT ('$DO YOU WISH DEBUG PRINTS: ? (Y/N):
        READ (5,32) DUM
        FLAG2=-1
        IF (DUM. EQ. 'Y') GO TO 44
        FLAC2=0
44
        WRITE (5,6)
        FORMAT ('SENTER DEPTH IN (M)SW, (F)SW OR (P)SIG BY '
6
        1, '(M#,F#,P#): [F]', T70)
        READ (5,7) RDU, RD
7
        FORMAT (1A1, F10, 2)
50
        WRITE (5,51) (IB, M=1,39), SRO, WUGO, WDG, CDG
        FORMAT (' ', 39A2, /, ' SEA LEVEL GARMENT ENSEMBLE '
51
        1, 'PROPERTIES', /
        2, '01-SPECFIC THERMAL RESISTANCE OF UNDERGARMENT: '
        3, '(CLD/CM)'
        4, T58, F8. 2, /, ' 2-UNIT THICKNESS OF UNDERGARMENT: '
        5, '(CM)'
        6, T58, F8. 2, /, ' 3-THICKNESS OF DUTER '
        7, 'GARMENT: (CM)', T58, F8. 4,/,' 4-THERMAL CONDUCTIVITY'
        8, ' OF OUTER GARMENT: (W/M*C)'
        9, T58, F8. 4, /, '$ENTER (1-4) TO ALTER, (R) '
        1, 'TO REINITIALIZE, (X) FOR NO '
        2, 'CHANGE:
                    1)
        READ (5,32) IT
        IF (IT. EQ. 'X') QO TO 58
        IF (IT. EQ. 'R') FL4=REINIT(1)
        IF (IT. EQ. 'R') GO TO 50
        DECODE (1,53,IT) IT
53
        FORMAT (I1)
        GO TO (54,55,56,57) IT
        GD TD 50
54
        WRITE (5,541)
        FORMAT ('$ ENTER 1 - SPECIFIC THERMAL RESISTANCE '
541
         1, 'OF UNDERGARMENT (CLO/CM): [F] ')
        READ (5,542) SRO
542
         FORMAT (F10.2)
         GO TO 50
55
         WRITE (5,551)
        FORMAT ('$ ENTER 2 - UNIT THICKNESS OF UNDERGARMENT'
551
         1, ' (CM): [F] ')
         READ (5,552) WUGO
552
         FORMAT (F10.3)
         QO TO 50
56
         WRITE (5,561)
         FORMAT ('$ ENTER THICKNESS OF DUTER GARMENT (CM): [F] ')
561
         READ (5,562) WOG
562
         FORMAT (F10.5)
         GO TO 50
         WRITE (5, 571)
57
571
         FORMAT ('$ ENTER THERMAL CONDUCTIVITY OF DUTER GARMENT '
         1, ' (W/M*C): [F] ')
```

```
READ (5,572) COG
572
        FORMAT (F10.5)
        GO TO 50
58
        WRITE (5,580) (IB, M=1,39), (M, BREG(M), TWUGO(M), WUGO
        1, (TWUGO(M) * WUGO), M=1, 9)
        FORMAT (' ', 39A2, /, ' REGIONAL UNDERGARMENT THICKNESS'
580
        1, ' (CM) ', /, 'O', T37, 'UNIT', T47, 'ACTUAL', /
        2, ' ', T4, 'ID #', T12, 'REGION', T23, 'MULTIPLIER', T35
        3, 'THICKNESS', T46, 'THICKNESS', /
        4, 9(5X, I1, 5X, 1A8, 5X, F6, 2, ' * ', F6, 2, '
                                                    = ', F8. 4, /),/
        5, '$ENTER (1-9) TO ALTER, (R) TO '
        6, 'REINITIALIZE, (X) FOR NO CHANGE:
        READ (5,32) IT
        IF (IT. EQ. 'X') GO TO 59
        IF (IT. EG. 'R') FL4=REINIT(2)
        IF (IT. EQ. 'R') GO TO 58
        DECODE (1,53,IT) IT
        WRITE (5,584) IT, BREG(IT)
584
        FORMAT ('$ENTER NEW MULTIPLIER FOR ', I1, '-', 1A8
         1, ': [F] ')
        READ (5,585) TWUGO(IT)
        FORMAT (F6.2)
585
         GO TO 58
59
        WRITE (5,590) (IB, M=1,39), (M, BREG(M), GALL(M), M=1,9)
        FORMAT (' ',39A2, /, ' ALLOWABLE REGIONAL HEAT FLUX'
590
         1, ' (W/M**2)', /, '0', T32, 'ALLOWABLE', /, ' ', T4, 'ID #'
        2, T12, 'REGION', T32, 'HEAT FLUX', /
        3,9(' ',5X, I1,5X, 1A8, 10X, F10, 2,/),/
         4, '$ENTER (1-9) TO ALTER, (R) TO '
         1, 'REINITIALIZE, (X) FOR NO CHANGE:
        READ (5,32) IT
         IF (IT. EQ. 'X') GO TO 60
         IF (IT. EQ. 'R') FL4=REINIT(3)
         IF (IT. EQ. 'R') GO TO 59
         DECODE (1,53,IT) IT
         WRITE (5,591) IT
591
         FORMAT ('SENTER ALLOWABLE HEAT FLUX FOR REGION '
         1, I1, ' (W/M**2): [F] ')
        READ (5,592) GALL(IT)
592
         FORMAT (F10.3)
         GO TO 59
60
         WRITE (5,600) (IB, M=1,39), (M, BREG(M), BF(M), M=1,9)
         FORMAT (' ',39A2//, ' REGIONAL BIASING FACTORS'
600
         1, ' (DIMENSIONLESS)',/
         2,'0',T4,'ID #'
         3, T12, 'REGION', T31, 'BIASING FACTOR', /
         4,9(' ',5X,I1,5X,1A8,10X,F10.2,/),/
         5,'$ENTER (1-9) TO ALTER, (R) TO '
         6, 'REINITIALIZE, (X) FOR NO CHANGE:
         READ (5,32) IT
         IF (IT. EQ. 'X') QD TD 609
         IF (IT. EQ. 'R') FL4=REINIT(4)
         IF (IT. EQ. 'R') GO TO 60
```

```
DECODE (1,53,IT) IT
        WRITE (5,601) IT
        FORMAT ('SENTER BIASING FACTOR FOR REGION '
601
        1, I1, ' (DIMENSIONLESS): [F] ')
        READ (5,602) BF(IT)
602
        FORMAT (F10.3)
        GD TD 60
609
        WRITE (5, 111)
        FORMAT ('$WRITE OUTPUT FILE WHERE: '
111
         1, '(T=SCREEN, F=DMPDAT. LST)
        READ (5,32) OUT
        WRITE (5, 10)
        FORMAT ('$ENTER # NODES: [I] ')
10
        READ (5,11) NN
11
        FORMAT (114)
         IF (REU. EQ. 'N') GO TO 43
        WRITE (5,16)
        FORMAT ('$DO YOU WISH TO COMPARE T, G, U VALUES WITH '
16
         1, 'EXP''T DATA: (Y/N)
                                 1)
        READ (5, 161) QCOMP, CH
161
        FORMAT (1A1,: F10.2)
         IF (QCDMP, NE. 'Y') GD TD 43
162
        NREC=0
        WRITE (5, 1621)
1621
        FORMAT ('SENTER TOTAL SURFACE AREA OF EXP''T'
         1' SUBJECT IN M++2: [F] '>
        READ (5,1622) TAR
         FORMAT (F10.2)
1622
         IF (TAR. LE. 0. 0) GO TO 162
163
         WRITE (5,1630)
                                                          1)
         FORMAT ('$ENTER EXPERIMENTAL DATA FILE NAME:
1630
         READ (5,1631) LFN, (FILE(L), L=1, LFN)
1631
         FORMAT (G, <LFN>A1)
         FILE(LFN+1)="0
                                  !WRITE NULL
         OPEN (UNIT=2, TYPE='OLD', ACCESS='DIRECT',
         1NAME=FILE, FORM='FORMATTED',
         2CARRIAGECONTROL='FORTRAN', READONLY,
         3RECORDSIZE=200, ERR=163)
         READ (2'1,164) NREC
164
         FORMAT (14)
         GO TO 114
43
         WRITE (5,431) (IB, M=1,39)
         FORMAT (' ', 39A2, /, 'SENTER DESIGN MEAN SKIN '
431
         1, 'TEMPERATURE (C): [F]', T65)
         READ (5,433) TDMS
433
         FORMAT (F10.3)
4330
         WR.ITE (5,432)
         FORMAT ('$ENTER AMBIENT TEMPERATURE >= 1.0 C: [F]', T65)
432
         READ (5,433) TA
         IF (TA.LT. 1.0) GO TO 4330
114
         WRITE (5,8)
8
         FORMAT ('$SELECT BODY REGION (1-9) OR (0) FOR ALL '
         1, 'REGIONS: [1]', T65)
```

```
READ (5,81) BR
81
        FORMAT (I10)
        WRITE (5,82)
        FORMAT ('$SELECT POSTURE OF SUBJECT (0-SIT, 1-STAND, '
82
         1, '2-PRONE): [I]', T65)
        READ (5,81) ATT
         ITOT=0
         IF (BR. EQ. 0) ITOT=-1
        PRT(1)=' '
        PV=2
         IF (REU. EQ. 'S'. OR. REU. EQ. 'N') GO TO 821
        PRT(2)='U'
         PRT(3)='N'
         PV=4
821
         DO 822 M=2,11
         PRT(PV)=PRTL(M)
822
         PV=PV+1
         PV=PV-1
         IF (ITOT. EQ. 0) GO TO 113
         DO 14 BR=1,9
         L0=5
113
         IF (OUT. EQ. 'T') GO TO 1130
         L0=3
         OPEN (UNIT=LO, NAME='SY: DMPDAT. LST')
1130
         WRITE (LO, 11301)
11301
         FORMAT ('0')
         IF (QCDMP. NE. 'Y') GO TO 1134
         DO 150 I=1, NREC
         READ (2'I+1,1131) EXP
         FORMAT (13F8. 2, 15F6. 2, F6. 1)
1131
         TA=EXP(27)
         IF (TA. GT. O. O) GD TD 11311
         DO 11310 J=2,7
         P(I,J)=-1.0
11310
         CONTINUE
11311
         TDMS=0. 0
         SWGT=0. 0
         DO 1132 M=14,25
  DROP VALUE & WEIGHT FROM SUM IF 'T' VALUE <= 0.0
         IF (EXP(M). LE. O. O) GO TO 1132
         TDMS=TDMS+(WGT(M-13)*EXP(M))
         SWGT=SWGT+WGT(M-13)
1132
         CONTINUE
         IF (SWGT. EQ. 0. 0) QO TO 11321
         TDMS=TDMS/SWGT
         P(I,1)=EXP(1)
11321
         WRITE (LO, 1133) EXP(1)
         FORMAT (' EXPERIMENTAL TIME: ', F8. 2)
1133
         LY= ' MSW '
1134
         IF (RDU. EQ. 'F') LY=' FSW'
         IF (RDU. EQ. 'P') LY=' PSI'
         T1=TR(TDMS, BR)
         WRITE (LO, 115) BR, ATT, TDMS, RD, LY, TA, BR, T1
```

```
FORMAT ('OBODY REGION: ', T56, I10, /
115
        1, ' POSTURE: O=SIT, 1=STAND, 2=PRONE', T56, I10, /
        2, 'DESIGN MEAN SKIN TEMPERATURE: ', T54, F10, 2, ' C', /
        3, ' REFERENCE DEPTH: ', T52, F10, 2, 1A4, /
        4, ' AMBIENT TEMPERATURE: ', T54, F10, 2, ' C', //
        5, ' PREDICTED TEMPERATURE FOR REGION ', I1, ': ', T54
        6, F10, 2, 'C')
        IF (NN. EQ. 1) QO TO 116
        WRITE (LO, 1151) NN
        FORMAT (' NUMBER OF NODES: ', T56, I10)
1151
116
        Q(BR)=0.0
        US=0. 0
        UN=0. 0
        ! NOTE:
                 HEAD(1) AND HAND(9) ARE SPHERES AND ARE THUS
                 MODELED AS HAVING ONE NODE ONLY FOR ALL
                 ATTITUDES, 0=SIT, 1=STAND, 2=LAY HORT.
                 THIGH(4) IS A HORTIZONTAL CYLINDER FOR
                 ATT = O(SIT) AND THUS HAS ONLY ONE NODE
                 WHEN ATT=1(STAND), 2(LAY HORT) THIGH(4)
                 MATCHS ALL THE OTHER CYLINDERS IN
                 ATTITUDE
        IF (BR. NE. 1. AND. BR. NE. 9. AND. (BR. NE. 4. OR. ATT. NE. 0))
        1 GO TO 1161
        J=1
        GO TO 118
         ! NOTE:
                 P(I,1)=TIME
                 P(I,2)=T EXPERIMENTAL
                 P(I,3)=T PREDICTED
                 P(I,4)=@ EXPERIMENTAL
                 P(I,5)=@ PREDICTED
                 P(I,6)=U EXPERIMENTAL
                 P(I,7)=U PREDICTED
                 P(I,8)=TDMS
                 P(I, 9)=TA
1161
         DO 13 J=1, NN
         IF (NN. EQ. 1) GO TO 118
         IF (J. EQ. 1) WRITE (LO, 11611)
         FORMAT ('0')
11611
         WRITE (LO, 1162) BR, J
         FORMAT (' REGION ', I1, ' NODE ', I4)
1162
         U=OHTC(J)
118
         !CHECK TO SEE IF CONVECTIVE HEAT TRANSFER COEFFICIENT
         ! WAS SUCCESSFULLY DETERMINED. FLAG3=0.0 => SUCCESS
         ! FLAG3=1. O AND FLAG3=2. O => FAILURE (SEE SUBROUTINE
         ! CHTC FOR DIFFERENCE BETWEEN FLAGG=1.0 AND 2.0)
         IF (FLAG3. GT. O. O) GO TO 148
         !CHECK TO SEE IF OHTC WAS SUCCESSFULLY DETERMINED.
         ! FLAG1 >= -1 SUCCESS, FLAG1 < -1 FAILURE.
         ! (SEE SUBROUTINE OHTC FOR MEANING OF VARIOUS
         ! VALUES OF FLAG1)
```

```
IF (FLAG1. GE. -1) GO TO 1191
        IF (FLAG1. NE. -3) GO TO 11801
        WRITE (LO, 1180) T3, TA
        FORMAT (' ESTIMATE OF OUTSIDE SURF. TEMP., ', F5. 2
1180
        1, 'LESS THAN AMBIENT TEMP., ', F5. 2)
        GO TO 11803
11801
        WRITE (LD, 11802) NTOL
11802
        FORMAT (' MAXIMUN # OF ITERATIONS (NTOL='
        1, 14, ') ALLOWED FOR ESTIMATING', /
        2, ' THE OUTSIDE SURFACE TEMPERATURE OF THE '
        3, 'ENSEMBLE BY THE SECANT METHOD EXCEEDED')
11803
        WRITE (LO, 11804)
11804
        FORMAT (20X, ' RUN TERMINATED !')
        GO TO 148
        IF DOING PRODUCTION MODE RUN (REU=N) THEN MUST APPLY
         BIASING FACTOR BF(BR) TO THE NODAL U VALUE .
         !NOTE: ONLY ON NODE IS DEFINED PER REGION IN THE
         PRODUCTION MODE.
         IF (REU. EQ. 'N'. OR. REU. EQ. 'S') U=U*BF(BR)
1181
        US=US+U
        UN=UN+1. 0
         QR=U*(T1-TA)
                                   !WATT/M2
         Q(BR)=Q(BR)+(QR*SAM(BR)/FLOAT(NN)) !WATTS
        IF (FLAG2. EQ. 0) GO TO 119
        WRITE (LO, 1182) RUG, ROG, ROBL, R1, R2, R3, T1, T3
         1, FLAG1, F(T3), CHTC(T3, R3), US, UN, QR, Q(BR)
1182
        FORMAT (' RUG, ROG, ROBL', 19, 3G15. 7, /
         1, '
              R1, R2, R3', 3G15, 7,/
        2, ′
              T1, T3', 2G15. 7, OP, /
         3, ′
              FLAG1, F(T3), CHTC(T3, R3) ', I7, 1P, 2G15, 7, /
         4, ′
              US, UN', 2G15.7,/
         5, '
              QR, Q(BR) ', 2G15.7)
         Q(BR)=G(BR)+(GR*SAM(BR)/FLOAT(NN)) !WATTS
C
         NOTE: MULTIPLYING NODAL HEAT FLUX 'GR' BY
C
         REGIONAL SURFACE AREA 'SAM(BR)' DIVIDED BY THE
C
         NUMBER OF NODES 'FLOAT(NN)' FORCES THE EXTRA AREA
C
         CONTRIBUTED BY A CYLINDER BOTTOM AND
C
         A CYLINDER TOP, REGIONS 6 AND 7
C
         RESPECTIVILY, TO BE INCLUDED IN THE
         LATTERAL SURFACE AREA.
                                   THIS IS
C
         CONSISTANT WITH THE AREA ASSUMED
C
         FOR HEAT LOSS IN THE DEVELOPMENT
C
         OF THE OHTC.
         IF (NN. EQ. 1) GO TO 126
119
         WRITE (LD, 125) (PRT(L), L=1, PV), J, U, J, QR
125
         FORMAT (<PV>A1, 'PREDICTED OHTC FOR NODE '
         1, I4, ': ', T47, F10. 2, ' W/M**2*C', /
         2, ' PREDICTED HEAT FLUX FOR NODE
         3, I4, ': ', T49, F10. 2, ' W/M**2', //)
         IF (BR. EQ. 1. OR. BR. EQ. 9. OR. (BR. EQ. 4. AND. ATT. EQ. 0))
126
         1 GO TO 142
```

```
13
        CONTINUE
142
        G(BR)=G(BR)/SAM(BR) !W/M**2
        U=US/UN
        WRITE (LO, 144) (PRT(L), L=1, PV), BR, U, BR, Q(BR), BR, QALL(BR)
144
        FORMAT (<PV>A1, 'PREDICTED OHTC FOR REGION ', I1, ': ', T47
        1,F10.2, ' W/M**2*C', /
        2, ' PREDICTED UNIT HEAT FLUX FOR REGION ', I1
        3, ': ', T49, F10. 2, ' W/M**2', /, ' ALLOWABLE UNIT HEAT FLUX '
        4, 'FOR REGION ', I1, ': ', T49, F10, 2, ' W/M**2')
        GA(BR)=GALL(BR)*SAM(BR)
        GP(BR)=G(BR)+SAM(BR)
        QSUPP(BR)=QP(BR)-QA(BR)
        QSUP=Q(BR)-QALL(BR)
        WRITE (LD, 131) GSUP, BR, QP(BR), BR, QA(BR), QSUPP(BR)
131
        FORMAT (' REQUIRED SUPPLEMENTARY HEAT FLUX: ', T49, F10. 2
        1, ' W/M**2', /
        2, ' PREDICTED RATE OF HEAT LOSS FOR REGION ', I1, ': '
        3, T50, F10. 2, ' WATTS', /, ' ALLOWABLE RATE OF HEAT LOSS '
         4, 'FOR REGION ', I1, ': ', T50, F10, 2, ' WATTS', /
         5, ' REGUIRED SUPPLEMENTARY HEATING: ', T50, F10, 2
         6, ' WATTS')
         IF (QCOMP. NE. 'Y') GO TO 148
        P(I,3)=T1
        P(I,5)=Q(BR)
                                   !WATTS/M2
         P(I,7)=US/UN
                                   !WATTS/M2*C
        P(I,8)=TDMS
                                   !T DES. MEAN SKIN
         P(I, 9)=TA
                                   !T AMBIENT
        TEXPT=0. 0
         UEXPT=0. 0
         QEXPT=0. 0
         SWGTT=0. 0
         SWGTQ=0. 0
         SWGTU=0. 0
         DO 1437 L=1,2
         M=COR(BR,L)
         IF (M. EQ. -1) GO TO 1437
   DROP VALUE & WEIGHT FROM SUM IF 'T' VALUE <= 0.0
         IF (EXP(M+13), LE. 0. 0) GO TO 1435
         TEXPT=TEXPT+(WGT(M)*EXP(M+13))
         SWCTT=SWCTT+WCT(M)
C DROP VALUE & WEIGHT FROM SUM IF 'Q' VALUE <= 0.0
1435
         IF (EXP(M+1). LE. 0. 0) GO TO 1436
         GEXPT=GEXPT+EXP(M+1)
                                   !WATTS
         SWQTQ=SWQTQ+WQT(M)
C DROP VALUE & WEIGHT FROM SUM IF 'Q' VALUE <= 0.0
         IF (EXP(M+1), LE. 0. 0. OR, EXP(M+13), LE. 0. 0) QD TD 1437
1436
         UEXPT=UEXPT+(EXP(M+1)/(EXP(M+13)-TA))
         SWCTU=SWCTU+WCT(M)
1437
         CONTINUE
         IF (SWGTT, EQ. 0. 0) GO TO 1438
         TEXPT=TEXPT/SWGTT
1438
         IF (SWGTG. LE. O. O) GO TO 1439
         GEXPT=GEXPT/(TAR*SWGTQ) !W/M2
```

```
1439
        IF (SWGTU, EQ. 0. 0) GO TO 1440
        UEXPT=UEXPT/(SWGTU*TAR)
1440
        P(I, 2)=TEXPT
        P(I,4)=QEXPT
        P(I,6)=UEXPT
        M=2
        PU(1)=','
        PU(2)=';'
         IF (COR(BR, 2), EQ. -1) M=1
         IF (M. EQ. 1) PU(1)=';'
        WRITE (LO, 1441) (COR(BR, L), PU(L), L=1, M), BR, TEXPT
         1, (COR(BR, L), PU(L), L=1, M), BR, UEXPT
         2, (COR(BR, L), PU(L), L=1, M), BR, GEXPT
1441
        FORMAT (' WGT''ED EXP''T TEMP, SITE(S) '
         1, <M>(12, A1), ' REGION ', I1, ': ', T54
         2, F10, 2, 'C', /
         3, ' WGT''ED EXP''T OHTC, SITE(S) '
         4, <M>(I2, A1), ' REGION ', I1, ': ', T47
         5, F10. 2, ' W/M**2*C', /
         6, ' WGT''ED EXP''T HEAT FLUX, SITE(S) '
         7, <M>(I2, A1), ' REGION ', I1, ': ', T49
         8,F10,2,' W/M**2')
         WRITE (LO, 149) (IB, M=1, 32)
148
         FORMAT (' ', 32A2)
149
         IF (QCOMP. NE. 'Y') GO TO 360
150
         CONTINUE
         IF (ITOT. EQ. -1. AND. BR. GT. 1) GO TO 152
         PRT(1)='('
         LCL=2
         IF (REU. EQ. 'S') GO TO 1501
         PRT(2)='U'
         PRT(3)='N'
         LCL=4
         DO 1502 M=2,10
1501
         PRT(LCL)=PRTL(M)
         LCL=LCL+1
1502
         PRT(LCL)=')'
         WRITE (5, 151)
         FORMAT ('$DO YOU WISH TO PLOT T''S, G''S, AND U''S? '
151
                   1)
         1, '(Y/N)
         READ (5,32) PLD
         IF (PLD. NE. 'Y') GO TO 249
         LABEL(1)='T C'
1510
         LABEL(2)='Q W/M2'
         LABEL(3)='U W/M2*C'
         WRITE (5,1511) (LABEL(M), (SCALY(M,N), N=1,3), M=1,3)
         FORMAT (' ',10X,'Y-AXIS SCALE FACTORS',//
1511
         1,10X,7X,'LY',10X,7X,'SY',10X,7X,'IY',/
         2,3(1X,AB,1X,3(F10,2,9X),/),/
         3, '$SELECT: (1=T, 2=G, 3=U, X=NO MORE CHANGES)
         READ (5,32) IT
         IF (IT. EG. 'X') GO TO 1517
         DECODE (1,1514, IT) L
```

```
1514
        FORMAT (I1)
        IF (L. LE. O. OR. L. GE. 4) GO TO 1517
        WRITE (5,1515) LABEL(L)
        FORMAT ('$ENTER', A8, ' LY, SY, IY SEPARATED BY COMMAS: '
1515
        1' [F] ')
        READ (5,1516) (SCALY(L,M),M=1,3)
1516
        FORMAT (3F10.3)
        GO TO 1510
        WRITE (5, 1518) LX, SX, IX
1517
1518
        FORMAT (' ', 10X, 'X-AXIS (TIME) SCALE FACTORS', //
        1, 10X, 7X, 'LX', 10X, 7X, 'SX', 10X, 7X, 'IX', /
        2, (1X, 'T, Q, U MIN', 3(F10, 2, 9X), /), /
         3, '$CHANGE X-AXIS? (Y/N)
        READ (5,32) IT
        IF (IT. NE. 'Y') GO TO 152
        WRITE (5,1519)
1519
        FORMAT ('SENTER LX, SX, IX SEPARATED BY COMMAS: [F] ')
        READ (5,1516) LX,SX,IX
        GD TO 1517
152
         IF (PLD. NE. 'Y') GO TO 249
        DO 200 K=1,3
        CALL NEWDEY (, 'DRO: COMPAR. VEC', 14)
         CALL PLOTST (4, 'IN', 1)
         CALL PLOT (1.0, 1.0, -3)
         CALL AXIS (0.0,0.0, 'TIME (MIN)',-10, LX, 0.0, SX, IX)
         GO TO (190,170,180) K
190
        LY=SCALY(K, 1)
         SY=SCALY(K, 2)
         IY=SCALY(K, 3)
        LYS=LY
         CALL AXIS (0.0,0.0, 'TEMPERATURE (C)',+15, LY, 90.0, SY, 1Y)
        LABEL(1)='T-EXPT
         LABEL(2)='T-PRED
         OPEN (UNIT=6, NAME='DR: COMPAR. OUT')
         WRITE (6,191) BREG(BR), LY, SY, IY
191
         FORMAT (' ',7X,1A8,/,' ',7X,'LY: ',F7.2,5X,'SY: '
         1, F7. 2, 5X, 'IY: '
         2, F7. 2, /, ' ', 7X, '* INDICATES POINT NOT PLOTTED; '
         3, ' ITS VALUE IS <= 0 OR < SY', /
         4, 12X, ' TIME ', 12X, '
                                 T-EXPT ', 10X
              T-PRED (,/)
         5, '
         CALL PLOTD(1, SYM, BR)
         CALL PLOTND
         CLOSE (UNIT=6)
         GO TO 200
170
         LY=SCALY(K, 1)
         SY=SCALY(K, 2)
         IY=SCALY(K, 3)
         LYS=LY
         CALL AXIS (0.0,0.0, 'HEAT FLUX (W/M2) ',+19,LY
         1, 90. 0, SY, IY)
         LABEL(1)='Q-EXPT
         LABEL(2)='Q-PRED
```

```
OPEN (UNIT=6; NAME='DR: COMPAR. OUT')
        WRITE (6,171) BREG(BR), (PRT(M), M=1, LCL), LY, SY, IY
        FORMAT (' ', 7X, 1A8, <LCL>A1, /, ' ', 7X, 'LY: ', F7. 2, 5X, 'SY: '
171
        1, F7. 2, 5X, 'IY: '
        2, F7. 2, /, ' ', 7X, '* INDICATES POINT NOT PLOTTED; '
        3, ' ITS VALUE IS <= 0 OR < SY', /
        4,12X, 'TIME ',12X, ' G-EXPT ',10X
         5, ' Q-PRED ',/)
        CALL PLOTD(3, SYM, BR)
        CALL PLOTND
        CLOSE (UNIT=6)
        GO TO 200
180
        LY=SCALY(K, 1)
        SY=SCALY(K, 2)
         IY=SCALY(K,3)
        LYS=LY
         CALL AXIS (0.0,0.0,'OHTC (W/M2*C)',+13,LY,90.0,SY,IY)
        LABEL(1)='U-EXPT
        LABEL(2)='U-PRED
         OPEN (UNIT=6, NAME='DR: COMPAR. OUT')
        WRITE (6, 181) BREG(BR), (PRT(M), M=1, LCL), LY, SY, IY
181
        FORMAT (' ',7X,1A8, <LCL>A1,/,' ',7X,'LY: ',F7.2,5X,'SY:'
         1, F7. 2, 5X, 'IY: '
         2, F7. 2, /, ' ', 7X, '* INDICATES POINT NOT PLOTTED; '
         3, ' ITS VALUE IS <= 0 OR < SY', /
         4,12X, 'TIME',14X, ' U-EXPT ',10X
         5, ' U-PRED ', /)
         CALL PLOTD (5, SYM, BR)
         CALL PLOTND
         CLOSE (UNIT=6)
200
         CONTINUE
249
         IF (ITOT. EQ. -1. AND. BR. GT. 1) GO TO 320
         WRITE (5,300)
300
         FORMAT ('$DO YOU WISH TO PLOT NORMALIZED T''S AND'
         1, ' BIOT #''S ? (Y/N) ')
         READ (5,32) PLN
         IF (PLN. NE. 'Y') GO TO 360
310
         LABEL(1)='TN'
         LABEL(2)='BI'
         WRITE (5,311) (LABEL(M), (SCALYN(M, N), N=1,3), M=1,2)
         FORMAT (' ',10X,'Y-AXIS SCALE FACTORS',/
311
         1, ' ', 8X, 'NON-DIMENSIONAL T''S & U''S', //
         2,10X,7X,'LY',10X,7X,'SY',10X,7X,'IY',/
         3,2(1X,A8,1X,3(F10.2,9X),/),/
         4, '$SELECT: (1=TN, 2=BI, X=NO MORE CHANGES)
         READ (5,32) IT
         IF (IT. EQ. 'X') GO TO 317
         DECODE (1,314,IT) L
         FORMAT (I1)
314
         IF (L. LE. O. OR. L. GE. 4) GO TO 317
         WRITE (5,315) LABEL(L)
315
         FORMAT ('$ENTER', A8, ' LY, SY, IY SEPARATED BY COMMAS: '
         1, ' [F] ')
```

```
READ (5,316) (SCALYN(L,M),M=1,3)
316
        FORMAT (3F10.3)
        GD TO 310
317
        WRITE (5,318) LX,SX,IX
        FORMAT (' ', 10X, 'X-AXIS (TIME) SCALE FACTORS', //
318
         1, 10X, 7X, 'LX', 10X, 7X, 'SX', 10X, 7X, 'IX', /
        2, (1X, 'TN, BI MIN', 3(F10, 2, 9X), /), /
        3, '$CHANGE X-AXIS? (Y/N)
        READ (5,32) IT
         IF (IT. NE. 'Y') GO TO 320
        WRITE (5,319)
319
        FORMAT ('$ENTER LX,SX,IX SEPARATED BY COMMAS: [R] ')
        READ (5,316) LX,SX,IX
         GO TO 317
320
         IF (PLN. NE. 'Y') GO TO 360
         DO 350 K=1.2
         CALL NEWDEY (, 'DRO: COMPARN. VEC', 15)
         CALL PLOTST (4, 'IN', 1)
         CALL PLOT (1.0, 1.0, -3)
         CALL AXIS (0.0,0.0, 'TIME (MIN)',-10, LX, 0.0, SX, IX)
         GO TO (330,340) K
330
         LY=SCALYN(K, 1)
         SY=SCALYN(K, 2)
         IY=SCALYN(K,3)
         LYS=LY
         CALL AXIS (0.0,0.0, 'NORMALIZED TEMPERATURE', +22, LY
         1, 90. 0, SY, IY)
         LABEL(1)='TN-EXPT '
         LABEL(2)='TN-PRED '
         OPEN (UNIT=6, NAME='DR: COMPARN. OUT')
         WRITE (6,331) BREG(BR), LY, SY, IY
331
         FORMAT (' ',7X,1A8,/,' ',7X,'LY: ',F7.2,5X,'SY: '
         1, F7. 2, 5X, 'IY: '
         2.F7. 2./. ' '.7X. '* INDICATES POINT NOT PLOTTED; '
         3, ' ITS VALUE IS <= 0 OR < SY', /
         4,12X, 'TIME ',13X, 'TN-EXPT ',10X
         5, ' TN-PRED ', /)
         CALL PLOTN(1, SYM)
         CALL PLOTND
         CLOSE (UNIT=6)
         GD TD 350
340
         LY=SCALYN(K, 1)
         SY=SCALYN(K, 2)
         IY=SCALYN(K, 3)
         LYS=LY
         CALL AXIS (O. O. O. O. 'BIOT NUMBER', +11, LY
         1,90.0,SY,IY)
         LABEL(1)='BI-EXPT '
         LABEL(2)='BI-PRED '
         OPEN (UNIT=6, NAME='DR: COMPARN. OUT')
         WRITE (6,341) BREG(BR), (PRT(M), M=1, LCL), LY, SY, IY
         FORMAT (' ',7X,1A8,CLCL>A1,/,' ',7X,'LY:',F7.2,5X,'SY:'
341
         1, F7. 2, 5X, 'IY: '
```

```
2.F7.2./, ' '.7X. '* INDICATES POINT NOT PLOTTED; '
      3, ' ITS VALUE IS <= 0 OR < SY', /
      4,12X, 'TIME ',13X, 'BI-EXPT ',10X
       5, ' BI-PRED ', /)
      CALL PLOTN(5, SYM)
      CALL PLOTND
      CLOSE (UNIT=6)
350
      CONTINUE
       IF (LO. EG. 5) GO TO 361
360
       CLOSE (UNIT=LO)
361
       IF (ITOT. EQ. 0) GO TO 15
14
       CONTINUE
       CLOSE (UNIT=2, DISPOSE='SAVE')
15
       IF (REU. EQ. 'X') GO TO 362
       GO TO 30
C********************
       !THIS CALL TO A SYSTEM LEVEL SUBROUTINE IS
       !USED TO DE-ATTACH THE TERMINAL. SEE
       !COMMENT AT TOP OF CODE ABOUT INITIAL
       !CALL TO 'WTGIO'
362
       CALL WTQID ("2000,"5)
STOP
       END
```

```
FUNCTION REINIT(I)
         REAL A(5), B(5), C(9), D(9), E(9), F(9), G(9), H(9)
         COMMON /SUIT/A, C
         1, /MISC/E, G
         DATA B/1.63, 0.1175, 2.27, 0.15875, 0.17307/
         1, D/1. 0, 1. 0, 1. 0, 1. 0, 1. 0, 2. 0, 1. 0, 1. 0, 1. 0/
         2, F/23. 3, 60. 0, 49. 7, 42. 4, 85. 0, 97. 0, 98. 9, 125. 25
         3, 265. 86/
         4, H/2, 56, 2, 56, 2, 22, 3, 45, 3, 13, 12, 50, 2, 27, 2, 17, 3, 45/
         GO TO (10, 20, 30, 40) I
10
         DO 11 J=1,5
         A(J)=B(J)
11
         CONTINUE
         GO TO 100
20
         DO 21 J=1.9
         C(J)=D(J)
21
         CONTINUE
         GD TO 100
30
         DO 31 J=1,9
         E(J)=F(J)
31
         CONTINUE
         GO TO 100
40
         DO 41 J=1,9
         G(J)=H(J)
41
         CONTINUE
100
         REINIT=I
         RETURN
         END
```

REAL FUNCTION OHTC(SN)

!THIS FUNCTION SYNTHESIZES THE PRESSURE AND TEMPERATURE !DATA AND PRODUCES A VALUE FOR THE OVERALL HEAT TRANSFER ! COEFFICIENT IN WATTS/SEC*C*(M**2) FOR THE GARMENT ! ENSEMBLE. !THE GARMENT ASSUMED IS THE NAVY'S DIVER THERMAL !PROTECTION ENSEMBLE !THE UNDERGARMENT IS MODELED AS DESCRIBED IN THE TEXT. !THE OUTER GARMENT IS MODELED AS A SOLID SLAB OF !NEOPRENE OF THICKNESS EQUAL TO OUTER GARMENT THICKNESS. !THE HEAT TRANSFER COEFFICIENT FOR THE OUTER BOUNDARY !LAYER IS DETERMINED FROM EQUATIONS DERIVED FROM !EXPERIMENTAL DATA. (SEE TEXT FOR DETAILS) C OHTC VARIABLES DEFINED IN MODULE OHTC !RDS = REGIONAL DATUM START=> REGION DEPTH BELOW SHOULDER REFERENCE (RDS=0.0 IF LAYING HORTIZONTAL) ! CR = CONDUCTIVITY RATIO=> RATIO OF THERMAL CONDUCTIVITIES OF AIR AT (0 MSW, 21.1 C) AND THE SUIT ENTRAPPED GAS AT AMBIENT DEPTH AND PRESSURE. ! DPCT = DECIMAL % CHANGE IN THINSULATE THICKNESS AS A FUNCTION OF HYDROSTATIC PRESSURE (DEPTH BELOW SHOULDERS) ! DZ = NODAL DISTANCE INCREMENT. DISTANCE BETWEEN NODES IN FINITE DIFFERENCE SOLUTION FOR EACH REGION. EACH CYLINDRICAL REGION IS DIVIDED INTO NODES ALONG IT'S LENGTH ONLY. SPHERES ARE TREATED AS HAVING A SINGLE NODE AT ALL TIMES. ! DZV = NODAL DEPTH INCREMENT. DEPTH CHANGE CAUSED BY EACH NODE WHEN REGION IS WHEN THE REGION IS VERTICAL. HORTIZONTAL THE NODES STEP OUTWARD IN THE HORTIZONTAL DIRECTION. WHEN THE REGION IS VERTICAL THE NODES STEP DOWNWARD IN THE VERTICAL PLANE. EDS = ELEMENT DISTANCE FROM SEA LEVEL, ELEMENT IMPLIES DIFFERENTIAL ELEMENT OF FINITE DIFFERENCE EQUATIONS. IE: DEPTH BELOW SEA LEVEL TO THE ELEMENT OF INTEREST) = START OF NODAL ELEMENT POSITION, DISTANCE FROM THE STARTING END OF THE REGION TO THE START OF THE NODAL ELEMENT. !SEPV = STARTING DEPTH OF THE NODAL ELEMENT FROM BEGINNING DEPTH OF THE REGION = MEAN TEMPERATURE BETW. AMBIENT AND THE SKIN SURFACE. ESTIMATED TEMPERATURE OF THE GAS ENTRAPPED IN THE UNGERGARMENT. !RDM = REFERENCE DEPTH (RD) CONVERTED TO METERS OF SEA WATER. (RD => DEPTH FROM SEA LEVEL TO

		SHOULDERS)
RED	=	REGIONAL ELEMENT DEPTH, DEPTH BELOW SHOULDERS
!		TO MID-POINT OF THE ELEMENT OF INTEREST.
!		(NOTE: IF SUBJECT LAYING HORTIZONTAL (ATT=2)
!		THEN RED=0.0)
ROBL	=	THERMAL RESISTANCE DUE TO THE PRESENCE OF THE
!		BOUNDARY LAYER ON THE OUTSIDE SURFACE OF THE
!		DUTER GARMENT
ROG	=	THERMAL RESISTANCE DUE TO THE PRESENCE OF THE
!		OUTER GARMENT
RUG	=	THERMAL RESISTANCE DUE TO THE PRESENCE OF THE
!		UNDER GARMENT
SRUGA	=	SPECIFIC THERMAL RESISTANCE OF THE
!		UNDERGARMENT DUE TO THE ENTRAPPED GAS AT THE
!		AMBIENT TEMPERATURE AND PRESSURE ONLY.
SRUGHA	=	SPECIFIC THERMAL RESISTANCE OF THE
Į.		UNDERGARMENT DUE TO BOTH HYDROSTATIC SQUEEZE
!		AND THE AMBIENT GAS AT DEPTH
! RUGHA	=	THERMAL RESISTANCE OF THE UNDER GARMENT DUE TO
!		BOTH HYDROSTATIC SQUEEZE AND THE AMBIENT GAS
!		AT DEPTH (IN UNITS OF CLO'S)
LAHQUA!	=	THERMAL RESISTANCE OF THE UNDER GARMENT,
!		RUGHA, CONVERTED FROM CLO'S TO SEC*C*M2/J
!		OR C*M2/WATT
!R1	=	RADIUS FROM CENTER OF CYLINDER/SPHERE TO EDGE
!		OF THE CYLINDER/SPHERE (M)
!R2	=	RADIUS FROM CENTER OF CYLINDER/SPHERE TO
!		OUTSIDE EDGE OF THE UNDERGARMENT (M)
!R3	#	RADIUS FROM CENTER OF CYLINDER/SPHERE TO
!	_	OUTSIDE EDGE OF OUTER GARMENT (M)
! TR2	=	THICKNESS OF THE UNDERGARMENT, WUGO, AT DEPTH THICKNESS REDUCED DUE TO HYDROSTATIC SQUEEZE
•	_	TEMPERATURE OF THE OUTER SURFACE OF THE
! T3	_	OF THE OUTER GARMENT
: LANOTEA	=1	LAGI, FTOL, TTOL, NTOL, AND REAL FUNCTION F ARE
		LVED IN FINDING THE OUTSIDE SURFACE
		URE, T3, OF THE OUTER GARMENT USING THE SECANT
		F FINDING THE REAL ROOTS OF THE FUNCTION F.
!FLAG1		FLAG INDICATING RESULTS OF THE SECANT METHOD
i LAVI		FOR FINDING THE OUTSIDE SURFACE TEMP. OF THE
i		OUTER GARMENT
į	=	-3 => ESTIMATE OF OUTSIDE SURFACE TEMP. > OR =
!		AMBIENT TEMPERATURE
!	=	-2 => MAX ALLOWED NUMBER OF ITERATIONS , NTOL,
!		EXCEEDED.
! !	=	-1 => VALUE OF FUNCTION F AT NEW TEMP.
!		EQUALS VALUE OF F AT OLD TEMP.
į	=	1 => COMPUTED CHANGE IN TEMPERATURE
!		LESS THAN OR EQUAL TO MINIMUM ALLOWED
!		TEMPERATURE SPECIFIED (TTOL).
!	=	2 => NEW VALUE OF FUNCTION F LESS THAN OR
!		EQUAL TO MINIMUM ALLOWED VALUE ,FTOL.
!FTOL	*	MINIMUM ALLOWED VALUE OF THE FUNCTION F

```
! TTOL
        = MINIMUM ALLOWED VALUE FOR THE TEMPERATURE STEP
          AT EACH ITERATION
INTOL
         MAXIMUM ALLOWED NUMBER OF STEPS THE SECANT
          PROCEDURE CAN TAKE
!TN1
        = NEW ESTIMATE OF THE TEMPERATURE
        = OLD ESTIMATE OF THE TEMPERATURE
! TNO
! DT
        = DIFFERENCE BETW. OLD AND NEW TEMPERATURE
          ESTIMATES
! B
        = ARRAY CONTAINING BODY DIMENSIONS FOR THE 9
          REGION MODEL MAN.
! COR
        = ARRAY CONTAINING THE CORRESPONDENCE BETWEEN
          THE 9 REGION AND 12 SEGMENT MODELS
        = ARRAY CONTAINING THE 12 SEGMENTAL HODY
! WGT
          SURFACE AREA WEIGHTS.
! *NOTE*
         THE FOLLOWING VARIABLES USED IN THIS MODULE
!WERE DEFINED IN MODULE - MAIN
          ATT, BR, COG, DR, FLAG2, LO, NN, RD, RDU, SRO, TA,
           TDMS, WDG, WUGO, TWUGO
!*NOTE* THE FOLLOWING VARIABLES USED IN THIS MODULE
!ARE TEMPERARY VARIABLE AND HAVE NO PERMINANT MEANING
           I, N
INTEGER ATT, BR, SN, FLAG2, FLAG1, COR
REAL MT
BYTE RDU
COMMON /BODY/B(9,3), COR(9,2), WGT(12)
1,/DEBUG/FLAG2,LD
2, /OHTCD/RUGHA, RUG, ROG, ROBL, R1, R2, R3, T1, T3, FLAG1
3, Q1A, Q13
4, /PROB/BR, ATT, RD, RDM, TA, NN, TDMS, DZ, DZV, FLAG3, RDS
5, RDU
6,/SUIT/WUGO, DR, SRO, WDG, CDG, TWUGO (9)
INTOL, FTOL, TTOL ARE TOLERANCE LIMITS USED IN FINDING
!T3 BY THE SECANT METHOD SUCH THAT F(T3)~=0:
!NTDL=> MAXIMUN NUMBER OF ITERATIONS ALLOWED
!FTOL=> ZERO TOLERANCE. IF F(T3) IS <= FTOL
        THEN F(T3)~=0
!TTOL=> ZERO TOLERANCE FOR THE DIFFERENCE BETWEEN
        T3(NEW) AND T3(OLD).
        IF (T3(NEW)-T3(OLD)) <= TTOL THEN DIFFERENCE IS
        ASSUMED ~= 0
DATA NTOL, FTOL, TTOL/300, 1. 0E-7, 1. 0E-3/
RDS=0. 0
RED=0. 0
DPCT=0. 0
IF (ATT. EQ. 2) QO TO 13
                          !2=PRONE
! ATT=Q OR ATT=1
                  (SIT, STAND)
IF (BR. GT. 1) GD TO 10
RDS=B(BR,2)*(-1.0)
GO TO 13
IF (BR. EQ. 2) QO TO 13
```

10

```
N=2
        IF (BR. GE. 7. AND. BR. LE. 9) N=7
11
        IF (BR. EQ. 7) GO TO 13
        DO 12 I=N, BR-1
        IF (I. EQ. 4. AND. ATT. EQ. 0) GO TO 110
        RDS=RDS+B(I,3)
        GO TO 12
        RDS=RDS+(B(I,2)/2.0)
110
        CONTINUE
12.
        IF (BR. NE. 4. OR. ATT. NE. 0) GO TO 13
         !BR=4 AND ATT=0
        RDS=RDS-(B(BR,2)/2,0)
         IF (BR. NE. 1. AND. 3R. NE. 9) GO TO 131
13
         !BR=1 OR BR=9
        DZ=B(BR, 2)
        SEP=0. 0
         SEPV=0.0
         DZV=B(BR, 2)
         IF (ATT. EQ. 2) DZV=0. 0
         GO TO 14
         DZ=B(BR, 3)/FLOAT(NN)
131
         SEP=DZ*FLOAT(SN-1)
         DZV=B(BR, 3)/FLOAT(NN)
         IF (ATT. EQ. 2) DZV=0. 0
         IF (ATT. EQ. O. AND. BR. EQ. 4) DZV=B(BR, 2)
         SEPV=DZV*FLOAT(SN-1)
         IF (ATT. EQ. 2) SEPV=0. 0
         IF (ATT. EQ. O. AND. BR. EQ. 4) SEPV=0. 0
         RDM=RD
14
         IF (RDU. NE. 'P') GO TO 15
         RDM=RD/1.461
                         !1.461 PSI/MSW
         IF (RDU. NE. 'F') GO TO 16
15
                                   !O. 3048 MSW/FSW
         RDM=RD+0. 3048
         IF (ATT. EQ. 2) GO TO 20
16
         RED=RDS+SEPV+DZV/2. 0
         IF (BR. EQ. 1) GO TO 20
         IF (RED. GT. O. 1711) GO TO 17
         DPCT=2. 358E-2*RED*100. 0
         GO TO 20
         !DPCT=>DECIMAL PERCENT CHANGE IN THICKNESS
         !**NOTE** THE MULTIPLICATION OF RED BY 100.0 IS TO
                     CONVERT THE UNITS FROM METERS TO CENTIMETERS
17
         DPCT=0.343+(3.784E-3*RED*100.0)-
         1(1.345E-5*((RED*100.0)**2))
         !TR=ESTIMATED REGIONAL TEMP. (12 POINT MODEL CONVERTED
             TO 9 POINT MODEL)
         MT = (T1 + TA)/2.0
20
         EDS=RDM+RED
         CR=TC(21. 1, 0)/TC(MT, EDS)
                                            !CONDUCTIVITY RATIO
21
         SRUGA=(SRO+CR)
         SRUGHA=SRUGA*(1.0~DR*DPCT)
         RUGHA=(SRUGHA+WUGO+TWUGO(BR))+(1.0-DPCT) !CLO'S
```

```
! ** NOTE **
        !RUGHA IS IN CLO'S
        !RUGHAJ IS RUGHA CONVERTED TO (SEC*C*M2/J)=(C*M2/WATT)
       RUGHAJ=RUGHA+0. 15477
                               !O.15477 M2*C/WATT/CLD
       IF (FLAG2, EQ. 0) GO TO 30
       WRITE (LO, 22) DZ, DZV, SEP, SEPV, RDM, RED, DPCT
       1, T1, MT, EDS, TC(21, 1, 0), TC(MT, EDS), CR
       2, SRUGA, SRUGHA, RUGHA, RUGHAJ
22
       FORMAT (' DZ, DZV', 1P, 2G15. 7, /
            SEP, SEPV', 2G15. 7, /
       2, '
            RDM, RED, DPCT', 3G15.7,/
       3, '
            T1, MT, EDS', 3G15, 7,/
       4, '
            TC(21.1,0), TC(MT, EDS) ', 2G15.7, /, ' CR', G15.7
       5, '
            SRUGA, SRUGHA', 2G15.7,/
       6, '
            RUGHA', G15. 7, 'CLO RUGHAJ', G15. 7
       7, 'M2*C/WATT')
30
       R1=B(BR,2)/2.0
                               ! M
       TR2=(WUGO*TWUGO(BR)*(1, O-DPCT))/100, 0 !M
       R2=R1+TR2
                               1 M
       R3=R2+(WDG/100.0)
                               ! M
       RUG=R1*RUGHAJ*LDG(R2/R1)/TR2
                                       !M2*C/WATT
       ROG=R1+LOG(R3/R2)/COG
                              !M2*C/WATT
        ! USING SECANT METHOD TO FIND TEMPERATURE OF OUTSIDE
        ! SURFACE OF DUTER GARMENT (T3).
        ! ASSUME (T1+TA)/2.0 <= T3 <= TA
        ! TA+(TA*0.01) USED AS INITIAL END POINT, TO AVOID
        ! DETERMINATION OF 'GRPR' PRODUCT WHEN THE WALL
         TEMPERATURE = AMBIENT TEMPERATURE
        TNO=TA+(TA*0.01)
        TN1=(T1+TA)/2.0
       IF (TN1. LE. TA) GO TO 430
       N=1
       DT=TN1-TNO
40
       N=N+1
        IF (N. GT. NTOL) GO TO 45
       FO=F(TNO)
       F1=F(TN1)
        IF (FLAG3. GT. O. O) RETURN
        IF (ABS(F1), LE, FTOL) GO TO 41
        IF ((F1-F0). EQ. Q. Q) GO TO 44
        DT=F1*DT/(FO-F1)
        TNO=TN1
        TN1=TN1+DT
        IF (TN1. LE. TA) GO TO 430
        IF (ABS(DT), LE. TTOL) GO TO 42
        GO TO 40
       FLAG1=2
41
                       !FTOL SATISFIED
```

```
GD TD 43
42
                         !TTOL SATISFIED
        FLAG1=1
43
        T3=TN1
        IF (T3. GE. TA) GO TO 431
430
        FLAG1=-3
        GO TO 46
431
        ROBL=R1/(R3*CHTC(T3,R3))
        OHTC=1.0/(RUG+RDG+RDBL)
        GO TO 46
44
        FLAG1=-1
                                  !F(TN1)-F(TN0) < 0
        GD TD 46
45
        FLAG1=-2
                                  INTOL EXCEEDED
46
        IF (FLAG2. EQ. 0) GO TO 47
        TMP=F(TN1)
        WRITE (LO, 461) T3, DT, TN1, TMP, Q1A, Q13
461
        FORMAT (' T3, DT, TN1', 1P, 3G15. 7, /
        1, ' F(TN1), Q1A, Q13', 3G15.7)
47
        RETURN
        END
```

```
REAL FUNCTION F(T)
C F(T)
                VARIABLES DEFINE IN MODULE F(T)
        !THIS MODULE IS A FUNCTION SUBROUTINE DEFINING
        !THE FUNCTION TO BE SOLVED SUCH THAT F(T)~=0.
        !THE FUNCTION RELATES THE HEAT LOSS THRU THE
        !COMPLETE ENSEMBLE TO THAT THRU THE UNDER GARMENT
        !AND THE OUTER GARMENT. THE UNKNOWN IN THIS
        EQUATION IS THE TEMPERATURE AT THE DUTSIDE
        SURFACE OF THE OUTER GARMENT.
        !THE VALUE OF T3 PASSED AS T IS SUBSTITUTED INTO THE
        !EQUATION FOR F(T) AND THE CALCULATED VALUE IS
        !PASSED BACK FOR USE IN THE SECANT METHOD OF ESTIMATING
        ! T3
C
        VARIABLES NEEDED FOR CALCULATION OF F(T)
                = FUNCTION SUBROUTINE FOR CALCULATING THE
                   COEFFICIENT OF HEAT TRANSFER THRU THE FREE
                   CONVECTION BOUNDARY LAYER
                = BODY REGION OF INTEREST, BR, PASSED TO THE
        ! IBR
                   SUBROUTINE
        ! ROG
                = THERMAL RESISTANCE OF OUTER GARMENT
        ! RUG
                = THERMAL RESISTANCE OF UNDER GARMENT
                 = ARGUMENT PASSED TO FUNCTION, ESTIMATE
        ! T
                   OF TO TEMPERATURE OF OUTSIDE SURFACE OF
                   THE DUTER GARMENT
                = TEMPERATURE - AMBIENT
        !TA
        !T1
                = TEMPERATURE OF THE CYLINDER/SPHERE SURFACE
        : T3
                = TEMPERATURE OF THE OUTSIDE SURFACE OF THE
                   OUTER GARMENT
                 = RADIUS TO REGION SURFACE/INNER GARMENT
                   INTERFACE
        ! R3
                 = RADIUS TO OUTER GARMENT/FLUID BOUNDARY LAYER
                   INFERFACE
  *NOTE* THE FOLOWING VARIABLE ARE DEFINED IN PREVIOUS MODULES
        !DZ, DZV, FLAG1, IATT, NN, RD, RDU, RUGHA, R1, R2, R3, TDMS
        BYTE RDU
        INTEGER FLAG1
        COMMON /OHTCD/RUGHA, RUG, ROG, ROBL, R1, R2, R3, T1, T3, FLAG1
        1, Q1A, Q13
        2, /PROB/IBR, IATT, RD, RDM, TA, NN, TDMS, DZ, DZV, FLAG3, RDS
        3, RDU
        HC=CHTC(T,R3)
        IF (FLAG3. GT. O. O) RETURN
        Q1A=(T1-TA)/(RUG+ROG+(R1/(R3*HC)))
        Q13=(T1-T)/(RUQ+RUQ)
        F=Q1A-Q13
        RETURN
        END
```

	REAL FUNCTION CHTC(T3,R3)
C	!THIS FUNCTION COMPUTES THE CONVECTIVE HEAT TRANSFER !COEFFICIENT FOR THE OUTER BOUNDARY LAYER IN !WATTS/SEC*C*(M**2). THE EQUATIONS USED WERE !DERIVED FROM EXPERIMENTAL DATA. (SEE TEXT FOR DETAILS)
C	INTEGER BR, COR, ATT, FLAG2, LO REAL LNU, LGRPR BYTE RDU COMMON /BODY/B(9,3), COR(9,2), WGT(12) 1/PROB/BR, ATT, RD, RDM, TA, NN, TDMS, DZ, DZV, FLAG3, RDS 2, RDU 3, /DEBUG/FLAG2, LO
C	!** NOTE ** ! ALL REFERENCES TO LOG IMPLY LOG BASE 10 (LOG10)
c	COEFFICIENTS FOR DETERMINATION OF THE GRASHOF AND PRANDTL NUMBER PRODUCT. USING: GRPR = (ALPHA)*(T WALL - T AMBIENT)*(L**3) WHERE: LOG (ALPHA) = BETA1*(LOG (T FILM))**BETA2 ALPHA = G*BETA*RHO**2*CP/MU*K T FILM = (T WALL + T AMBIENT) / 2.0 GRPR = GRASHOF* * PRANDTL* THE COEFFICIENTS WERE FOUND BY FITTING THE EQUATION TO EXPERIMENTAL DATA, SEE TEXT FOR DETAILS.
c	COEFFICIENTS FOR DETERMINATION OF THE THERMAL CONDUCTIVITY OF WATER AS A FUNCTION OF TEMPERATURE IN DEGREES C. THE COEFFICIENTS WERE FOUND BY FITTING THE EQUATION TO EXPERIMENTAL DATA, SEE TEXT FOR DETAILS. K = CFO + CF1*T DATA BETA1, BETA2/9, 80714, 0, 12733/ 1, CFO, CF1/0, 56662, 1, 7977E-3/
L	!COEFFICIENTS FOR DETERMINATION OF LOG (NU) AS A !FUNCTION OF LOG (GRPR) FOR VERTICAL CYLINDERS !LOG(NU) = VCO + VC1*(LOG(GRPR)) + VC2*((LOG(GRPR))**2) !THE COEFFICIENTS WERE FOUND BY FITTING THE EQUATION TO !EXPERIMENTAL DATA, SEE TEXT FOR DETAILS. !
C	COEFFICIENTS FOR DETERMINATION OF LOG (NU) AS A !FUNCTION OF LOG (GRPR) FOR SPHERES !LOG(NU) = SO*LOG(GRPR) + S1 !THE COEFFICIENTS WERE FOUND BY FITTING THE EQUATION TO !EXPERIMENTAL DATA, SEE TEXT FOR DETAILS.

```
COEFFICIENTS FOR DETERMINATION OF LOG (NU) AS A
        !FUNCTION OF LOG (GRPR) FOR HORTIZONTAL CYLINDERS
        !LOG(NU) = HCO*LOG(GRPR) + HC1
        !THE COEFFICIENTS WERE FOUND BY FITTING THE EQUATION TO
        !EXPERIMENTAL DATA, SEE TEXT FOR DETAILS.
        DATA VCO, VC1, VC2/9, 1934, -2, 4128, 0, 1817/
        1, SQ, S1/0, 46486, -1, 9726/
        2, HCO, HC1/0, 2486, -0, 4483/
C CHTC
                VARIABLES DEFINED IN MODULE CHTC
        ! ALPHA
                = G*BETA*RHO**2*CP/MU*K
        !BETA
                = LOG (ALPHA)
        !BETA1
                = COEFFICIENT SEE ABOVE
        !BETA2
                = COEFFICIENT SEE ABOVE
        ! CF
                = THERMAL CONDUCTIVITY OF WATER AT TEMPERATURE
        !CFO
                = COEFFICIENT SEE ABOVE
        !CF1
                = COEFFICIENT SEE ABOVE
        ! CL
                = CHARACTERISTIC LENGTH FOR FREE CONVECTION
                   FOR VERTICAL CYLINDERS = LENGTH OF CYLINDER
                  FOR HORTIZONTAL CYLINDERS = DIAMETER OF
                   CYLINDER
                   FOR SPHERES = DIAMETER
        ! GR
                = GRASHOF NUMBER, PRANDTL NUMBER PRODUCT
        ! HCO
                = COEFFICIENT SEE ABOVE
        ! HC1
                = COEFFICIENT SEE ABOVE
        !LGRPR
                = LOG (GRPR)
        !LNU
                = LOG (NU)
                   NU = NUSSELT NUMBER
        ! SO
                = COEFFICIENT SEE ABOVE
        !S1
                = COEFFICIENT SEE ABOVE
                 = TEMPERATURE OF FILM
        !TF
                 = (T SURFACE + T AMBIENT GAS)/2.0
        ! VCO
                 = COEFFICIENT SEE ABOVE
        ! VC1
                = COEFFICIENT SEE ABOVE
        !VC2
                = COEFFICIENT SEE ABOVE
                 - ARRAY CONTAINING BODY REGION DIMENSIONS
        ! B
        !FLAG3
                 = INTEGER VARIABLE USED TO INDICATE SUCCESS OR
                   FAILURE OF THIS SUBROUTINE.
                 = 0.0
                         CHTC DETERMINED SUCCESSFULLY
                         CHTC NOT DETERMINED, ESTIMATED FILM
                         TEMPERATURE LESS THAN 1.0
                         CHTC NOT DETERMINED, GRASHOF*PRANDTL
                         PRODUCT IS EQUAL TO ZERO.
C *NOTE* THE FOLLOWING VARIABLES WERE DEFINED IN PREVIOUS
        ! MODULES:
        !BR, TA, T3
  *NOTE* ARRAYS COR AND WGT ARE PASSED TO THIS MODULE IN
         !LABELED COMMON BUT ARE NOT USED IN THIS MODULE.
        FLAG3=0.0
```

```
GO TO (1,2) ATT
C
        ATT=0 SITTING
        GO TO (11, 10, 10, 12, 10, 10, 10, 10, 11) BR
C
        ATT=1 STANDING
        QQ TQ (11, 10, 10, 10, 10, 10, 10, 10, 11) BR
C
        ATT=2 PRONE
2
        GO TO (11, 12, 12, 12, 12, 12, 12, 12, 11) BR
C
         VERTICAL CYLINDERS
10
        CL=B(BR,3)
                          · M
         ASSIGN 105 TO LRET
         GD TD 20
105
        LNU=VCO+(VC1*LGRPR)+(VC2*(LGRPR**2.0))
         GO TO 15
        SPHERE
11
         CL=2. 0*R3
                          ! M
         ASSIGN 115 TO LRET
         GD TD 20
115
         LNU=(SO*LGRPR)+S1
         GO TO 15
         HORTIZONTAL CYLINDER
12
         CL=2. 0*R3
                          ! M
         ASSIGN 125 TO LRET
         GO TO 20
125
         LNU=(HCO*LGRPR)+HC1
15
         CF=CFO+(CF1*TF)
                                   !W/M*C
         CHTC=(10.0**LNU)*CF/CL
                                  ! W/M2+C
         RETURN
         TF=(T3+TA)/2.0
20
         IF (TF. LT. 1. 0) GD TO 21
         BETA=BETA1*(LOG10(TF)**BETA2)
         ALPHA=(10.0**BETA)
         GRPR=ALPHA*(CL**3.0)*(T3-TA)
         IF (GRPR. LE. O. O) GO TO 23
         LGRPR=LOG10(GRPR)
         GO TO LRET
21
         WRITE (LO, 22)
         IF (LO. NE. 5) WRITE (5,22)
22
         FORMAT (' SYSTEM WILL NOT EXPONENTIATE A NEGATIVE ",/
         1, ' BASE BY A REAL EXPONENT', /
         2,20X, 'RUN TERMINATED !')
         FLAQ3=1.0
         RETURN
23
         WRITE (LO, 24)
         IF (LO. NE. 5) WRITE (5, 24)
         FORMAT (' THE LOGARITHM OF ZERO '
24
         1, 'IS UNDEFINED', /
         2,20X, ' RUN TERMINATED !')
         FLAG3=2. 0
25
         RETURN
         END
```

REAL FUNCTION TR(TDMS, BR)

!THIS FUNCTION COMPUTES THE PREDICTED REGIONAL
!TEMPERATURES FOR THE 9 REGION MODEL.
!THE PREDICTIVE EQUATIONS USED WERE DERIVED FOR
!THE 12 SEGMENT HODY MODEL WITH EXPERIMENTAL
!DATA. (SEE TEXT FOR DETAILS)
!THE PREDICTIONS FOR THE 12 SEGMENTS WERE
!COMBINED BY A WEIGHTED SUM USING THE HODY
!WEIGHTS CORRESPONDING TO THE SUMMED SEGMENTS.
!THE CORRESPONDENCE BETWEEN THE 9 REGION AND 12 SEGMENT
!MODELS IS SHOWN IN ARRAY COR, BELOW. FOR MORE DETAIL
!SEE MODULE MAIN

:		
!ROW#	9 REGIOM	12 SEGMENT MODEL
! =>BR	MODEL NAME	CORRESPONDING SEGMENTS NAME(ID#)
į		ID #'S ARE IN ARRAY COR(9,2)
! 1	HEAD	HEAD(1),(-1)
12	TORSO	CHEAT(2), UPPER BACK(4)
13	ABDOMEN	ABDOMEN(3), LOWER BACK(5)
14	THIGH	FRONT THIGH(8), REAR THIGH(10)
! 5	CALF	FRONT CALF(9), REAR CALF(11)
!6	FOOT	FOOT(12),(-1)
!7	UPPER ARM	ARM(6),(-1)
18	LOWER ARM	ARM(6),(-1)
19	HAND	WRIST(7),(-1)
1		NOTE (-1) INDICATES THAT ONLY
1		ONE CORRESPONDING SEGMENT IS
•		AVAILABLE FROM 12 SEGMENT MODEL
! 6 ! 7 ! 8	FOOT UPPER ARM LOWER ARM	FOOT(12),(-1) ARM(6),(-1) ARM(6),(-1) WRIST(7),(-1) NOTE (-1) INDICATES THAT ONLY ONE CORRESPONDING SEGMENT IS

C TR

VARIABLE REQUIRED AND LOCALLY DEFINED
!TDMS = DESIGN MEAN SKIN TEMPERATURE. MEAN
! SKIN TEMPERATURE AT WHICH TO COMPUTE
! THE PREDICTED REGIONAL TEMPERATURES.
!BR = BODY REGION OF INTEREST. ONE OF THE
! 9 REGION MODEL REGIONS.

COR = ARRAY CONTAINING CORRESPONDENCE BETWEEN 9
REGION AND 12 SEGMENT MAPS

!SWGT = SUM OF WEIGHTS CORRESPONDING TO THE 12 ! SEGMENTS SUMMED.

!PRED = FUNCTION SUBROUTINE WHICH CALCULATES THE
! 12 SEGMENTAL PREDICTED TEMPERATURES AT
A GIVEN MEAN SKIN TEMPERATURE, TDMS
! AND SEGMENT J

!WGT = ARRAY CONTAINING THE 12 HODY SURFACE WEIGHTS

NOTE: ARRAY B IS PASSED TO THIS MODULE IN LABELED COMMON BUT THIS ARRAY IS UNUSED IN THIS MODULE.

NOTE: VARIABLES I AND J ARE TEMPORARY VARIABLES USED AS DO LOOP INDICES AND COUNTERS.

! NOTE: VARIABLES I AND J ARE TEMPORARY VARIABLES USED

AS DO LOOP INDICIES AND COUNTERS.

```
INTEGER COR, BR
        COMMON /BODY/B(9,3), COR(9,2), WGT(12)
        TR=0. 0
        SWQT=0. 0
        ! NOTE:
                THERE IS NO CHECKING FOR O. O VALUES
                IN THE SUM SINCE THE PREDICTED VALUES
                CAN NOT BE ZERO UNLESS TDMS=0.0.
                TDMS CAN NOT BE ZERO BY ACCIDENT IT
                MUST BE SPECIFIED AS ZERO IF THAT
                IS THE DESIRED VALUE.
        DO 10 I=1,2
        J=COR(BR, I)
        IF (J. EQ. -1) GO TO 10
        SWGT=SWGT+WGT(J)
        TR=TR+(PRED(J, TDMS)*WGT(J))
10
        CONTINUE
        TR=TR/SWGT
        RETURN
        END
```

REAL FUNCTION PRED(REG, TSKM) !FUNCTION PRED DETERMINES THE PREDICTED 12 SEGMENTAL !TEMPERATURES FROM EQUATIONS DERIVED USING !EXPERIMENTAL DATA AND BASED ON A KERSLAKE !TYPE MODEL. (SEE TEXT FOR DETAILS) C PRED VARIABLES REQUIRED AND LOCALLY DEFINED = SEGMENT FOR WHICH TO PREDICT !REG SKIN TEMPERATURE = MEAN SKIN TEMPERATURE TO USE AS ! TSKM INDEPENDENT ARGUMENT IN THE EQUATIONS. USUALLY THE DESIGN MEAN SKIN TEMPERATURE. !KA - ARRAY CONTAINING THE COEFFICIENTS FOR THE PREDICTIVE EQUATIONS = CONSTANT USED IN THE PREDICTIVE EQUATIONS ! KR REAL KA, KR

REAL KA, KR
INTEGER REG
COMMON /PREDD/KA(12), KR
PRED=TSKM+(KA(REG)*KR)
RETURN
END

REAL FUNCTION TC (TDC, Z) !THE FUNCTION SUBROUTINE TC(TDC, Z) DETERMINES THE !THERMAL CONDUCTIVITY OF AIR CORRESPONDING TO THE VALUES !OF TEMPERATURE, T C, AND PRESSURE, Z MSW PASSED. !THE VALUE IS DETERMINED BY A METHOD OF TWO !DIMENSIONAL LINEAR INTERPOLATION ADAPTED FROM CARNAHAN, LUTHER, AND WILKES, "APPLIED NUMERICAL !METHODS", P 63, PRB 1.28, JOHN WILEY & SONS, INC., 1969 !ARRAY C - CONTAINS THERMAL CONDUCTIVITY DATA FOR AIR AT - PRESSURES - 14. 7, 30. 0, 50. 0, 100. 0, 200. 0 PSIA - TEMPERATURES - 30.0,50.0,70.0,90.0,110.0, 130.0 F **NOTE** CONDUCTIVITIES HAVE UNITS BTU/SEC FT F AND VALUES MUST BE MULTIPLIED BY 1. 0E-06 DATA TAKEN FROM: - U.S. NAVY DIVING GAS MANUAL, - NAVSHIPS 0994-003-7010, 1971 - PAGE T-4 (AIR DATA) !LAYOUT OF ARRAY C 130.0 50.0 70.0 90.0 110.0 130.0 F 13. 93 4.06 4. 19 4. 32 4. 45 4. 58 130.0 4. 07 13. 93 4. 20 4. 33 4. 46 4. 59 13. 95 4.08 4, 34 4, 47 4, 59 150.0 4. 21 4. 37 4. 49 4. 62 1100.0 13. 98 4. 11 4. 24 14.03 4. 16 **!200.0** 4. 29 4, 42 4, 54 4, 66 ! Psia C*NOTE* IF THE VALUE OF 'C' RETURNED TO CALLING MODULE IS !NEGATIVE THEN THE VALUE OF 'T' OR 'Z' WAS OUT OF !RANGE FOR THE TABLE STORED IN ARRAY C. C TC VARIABLES REQUIRED AND LOCALLY DEFINED = TEMPERATURE OF INTEREST IN DEGREES C ! TDC - DEPTH BELOW SURFACE IN METERS OF SEAWATER ! Z = COMPONENT OF EQUATION FOR TC !A (SINGLE TERM COMPUTED SEPARATELY) = COMPONENT OF EQUATION FOR TC (SINGLE TERM COMPUTED SEPARATELY) = LOGICAL UNIT NUMBER AT WHICH TO PRINT ! LO INFORMATION. !P = ABSOLUTE PRESSURE => DEPTH IN METERS OF SEAWATER, Z, CONVERTED TO PSIA = TEMPERATURE DEGREES F => TEMPERATURE DEGREES C. TDC. CONVERTED TO DEGREES F

USED AS DO LOOP INDICES AND COUNTERS.

NOTE: VARIABLES I, II, IJ AND J ARE TEMPORARY VARIABLES

BYTE IG INTEGER FLAG2

```
COMMON /DEBUG/FLAG2, LO
        2,/TRNOSQ/C(6,7)
C
        CONVERT Z METERS OF SEA WATER TO PSI ABSOLUTE
        P=((64.15*100.0*Z)/(2.54*(12.0**3)))+14.7
C
        REDUCE P TO 1 SIGNIFICANT DIGIT AFTER DECIMAL PT
         P=((AINT((P+0.05)*10.0))/10.0)
C
        CONVERT DEGREES C TO F
         T=(((TDC+273.15)*1.8)-459.67)
         IF (P. LT. C(2, 1), OR. T. LT. C(1, 2)
         1. OR. P. GT. C(6, 1). OR. T. GT. C(1, 7)) GO TO 20
         DO 10 I=2,6
         IF (C(I,1), LT.P) GO TO 10
         II=I
         IF (C(I,1). NE. P) II=II-1
         GD TO 12
10
         CONTINUE
         GO TO 20
12
         DO 13 J=2,7
         IF (C(1, J), LT, T) GO TO 13
         IJ=J
         IF (C(1, J). NE. T) IJ=IJ-1
         GD TO 15
13
         CONTINUE
         60 TO 20
15
         B=(T-C(1,IJ))/(C(1,IJ+1)-C(1,IJ))
         IF (T. EQ. C(1, IJ)) B=0. 0
         A=(P-C(II,1))/(C(II+1,1)-C(II,1))
         IF (P. EG. C(II, 1)) A=0. 0
         TC=((1, Q-A)*(1, Q-B)*C(II, IJ))+(A*(1, Q-B)*C(II+1, IJ))
         1+(B*(1.0-A)*C(II, IJ+1))+(A*B*C(II+1, IJ+1))
         CORRECT TO TO BE IN WATTS/M*C
         1. OE-6 IS APPLIED TO YIELD CORRECT VALUES
C
         TC=TC*(1. QE-6)*6230, 551
         6230.551 J/M*C/BTU/FT*F
C
         RETURN
20
         TC=O. O
         WRITE(LO, 11) T.P
         FORMAT (' ', 10X, 'T=', F10. 2, ' OR P=', F10. 2
11
         1, ' OUT OF RANGE OF TABLE')
         RETURN
         END
```

SUBROUTINE PLOTD (IR, PSYM, BR) !PLOTD IS A SUBROUTINE FOR PLOTTING T'S, Q'S, AND U'S BOTH PREDICTED AND EXPERIMENTAL VERSUS TIME. C PLOTD VARIABLES REGUIRED AND LOCALLY DEFINED = OFFSET INTO ARRAY P AT WHICH TO PICK ! IR UP BOTH THE PREDICTED AND EXPERIMENTAL DATA. P(ROW, IR+1) = EXPERIMENTAL P(ROW, IR+2) = PREDICTED = ARRAY (PSYM(2)) CONTAINING THE INTEGER NUMBERS INDICATING THE SYMBOLS TO BE USED FOR THE EXPERIMENTAL AND PREDICTED CURVES RESPECTIVELY. (SEE DIGITAL EQUIPMENT CORP. MANUAL PLXY-11M, USER'S GUIDE FOR DETAILS) BR = BODY REGION WHICH THE EXPERIMENTAL AND PREDICTED VALUE CORRESPOND TO. !LYS = Y-AXIS LEVEL FOR LABLES. INITIALLY SET AT LY ! NREC = NUMBER OF TIME RECORDS TO PLOT (IE: 1 TO NREC) BYTE VARIABLE CONTAINING EITHER '*' ! DE OR ' ' (SPACE). IT IS USED TO FLAG THE EXPERIMENTAL DATA POINTS NOT PLOTED BECAUSE THEY ARE EITHER <= 0 OR < SY. SY IS THE STARTING VALUE FOR THE Y-AXIS. BYTE VARIABLE CONATAINING EITHER '*' OR ' ' (SPACE). THIS VARIABLE IS USED IN THE SAME MANNER AS VARIABLE DE EXCEPT THAT DP IS USED FOR THE PREDICTED VALUES. = ARRAY CONTAINING NAMES OF BODY REGIONS ! BREG ARRANGED TO CORRESPOND TO BR !LABEL = ARRAY CONTAINING LABEL TEXT FOR THE PLOTS = ARRAY CONTAINING THE DATA TO BE PLOTTED NOTE: VARIABLES E, F, G, J, K AND L ARE TEMPORARY VARIABLES USED FOR DUMMY ARGUMENTS, DO LOOP INDICES AND COUNTERS. NOTE: THE FOLLOWING VARIABLE ARE DEFINED IN A MANNER NECESSARY TO SATISFY THE DEC PLXY-11M SUBROUTINE'S SPECIFICATIONS = X-AXIS INCREMENT => # UNITS PER PLOT UNIT ! IX ! IY = Y-AXIS INCREMENT => # UNITS PER PLOT UNIT !LX = X-AXIS LENGTH IN PLOT UNITS !LY = Y-AXIS LENGTH IN PLOT UNITS !SX = X-AXIS STARTING VALUE !SY = Y-AXIS STARTING VALUE ! XP = ARRAY USED TO PASS X-AXIS VALUES TO PLXY-11M SUBROUTINE LINE ! YP - ARRAY USED TO PASS Y-AXIS VALUES TO

PLXY-11M SUBROUTINE LINE

```
REAL LX, SX, IX, LY, SY, IY, LYS, XP(125), YP(125)
        REAL*8 LABEL(3), BREG(10)
         INTEGER PSYM(2), BR
        BYTE DE, DP, REU 'RT
        COMMON /PLOT/F , .25, 9), LX, SX, IX, LY, SY, IY, LYS, LABEL, NREC
         1, BREG, XP, YP, PD(125, 3), LCL, CH, REU, PRT(13)
        SL=3. 0
        IF (CH. GT. O. O) SL=CH
        CALL SYMBOL (LX-SL, LYS-0. 20, 0. 1169, BREG(BR), 0. 0, +8)
         IF (IR. EQ. 1) GO TO 10
         CALL SYMBOL (999., 999., 0.1169, PRT, 0.0, +LCL)
10
         CALL PLOT (0.0,0.0,+3)
        LYS=LYS-0. 20
        DO 13 J=1,2
        L=O
         DO 12 K=1, NREC
         IF (J. GT. 1) GO TO 115
         DE=' '
C
         CHECKING EXP'T VALUE TO BE IN RANGE OF PLOT
         IF (P(K, IR+1), LE. O. OR, P(K, IR+1), LT. SY) DE='*'
         DP='
C
         CHECKING PRED VALUES TO BE IN RANGE OF PLOT
         IF (P(K, IR+2), LE. O. OR, P(K, IR+2), LT, SY) DP='*'
         WRITE (6,11) P(K,1),P(K,IR+1),DE,P(K,IR+2),DP
11
         FORMAT (10X, F8. 2, 10X, F10. 2, 1A1, 9X, F10. 2, 1A1)
115
         IF (P(K, J+IR), LE. O. O. OR, P(K, J+IR), LT, SY) GO TO 12
         L=L+1
         XP(L)=P(K,1)
         YP(L)=P(K, J+IR)
         CONTINUE
12
         XP(L+1)=SX
         XP(L+2)=IX
         YP(L+1)=SY
         YP(L+2)=IY
         CALL PLOT (0.0,0.0,+3)
         CALL LINE (XP, YP, L, 1, +1, PSYM(J))
         CALL SYMBOL (LX-SL, LYS-0. 20, 0. 1169, LABEL(J), 0. 0, +8)
         CALL WHERE (E,F,G)
         CALL SYMBOL (E,F+(0.1169/2.0), 0.1169, PSYM(J), 0.0,-1)
         CALL WHERE (E, LYS, G)
         LYS=LYS-(0.1169/2.0)
13
         CONTINUE
         RETURN
         END
```

C	SUBROUT	INE PLOTN(IR, PSYM)
C	! TEMPER	IS A SUBROUTINE FOR PLOTTING NORMALIZED ATURES AND BIOT NUMBERS REDICTED AND EXPERIMENTAL VERSUS TIME.
C PLOTN	!IR	VARIABLES REQUIRED AND LOCALLY DEFINED = OFFSET INTO ARRAY P AT WHICH TO PICK UP BOTH THE PREDICTED AND EXPERIMENTAL DATA. P(ROW, IR+1) = EXPERIMENTAL
	! PSYM	P(ROW, IR+2) = PREDICTED
	BR	MANUAL PLXY-11M, USER'S GUIDE FOR DETAILS) = BODY REGION WHICH THE EXPERIMENTAL AND PREDICTED VALUE CORRESPOND TO.
	RMD LYS	= DEPTH IN MSW TO THE MIDDLE OF THE REGION. = Y-AXIS LEVEL FOR LABLES. INITIALLY SET AT LY
	NREC	the state of the s
	DE	= BYTE VARIABLE CONTAINING EITHER '*' OR ' (SPACE). IT IS USED TO FLAG THE EXPERIMENTAL DATA POINTS NOT PLOTED BECAUSE THEY ARE EITHER <= 0 OR < SY. SY IS THE STARTING VALUE
	! !DP !	FOR THE Y-AXIS. BYTE VARIABLE CONATAINING EITHER '*' OR ' ' (SPACE). THIS VARIABLE IS USED IN THE SAME MANNER AS VARIABLE DE EXCEPT THAT DP IS USED FOR THE PREDICTED
	BREG	VALUES. = ARRAY CONTAINING NAMES OF BODY REGIONS ARRANGED TO CORRESPOND TO BR
	LABEL	= ARRAY CONTAINING LABEL TEXT FOR THE PLOTS = ARRAY CONTAINING THE DATA TO BE PLOTTED
	NOTE:	VARIABLES E, F, G, J, K AND L ARE TEMPORARY VARIABLES USED FOR DUMMY ARGUMENTS, DO LOOP INDICES AND COUNTERS.
	NOTE:	THE FOLLOWING VARIABLE ARE DEFINED IN A MANNER NECESSARY TO SATISFY THE DEC PLXY-11M SUBROUTINE'S SPECIFICATIONS
	!IX !IY	= X-AXIS INCREMENT => # UNITS PER PLOT UNIT = Y-AXIS INCREMENT => # UNITS PER PLOT UNIT
	!LX !LY !SX	= X-AXIS LENGTH IN PLOT UNITS = Y-AXIS LENGTH IN PLOT UNITS = X-AXIS STARTING VALUE
	: 5 X ! SY ! XP	= Y-AXIS STARTING VALUE = Y-AXIS STARTING VALUE = ARRAY USED TD PASS X-AXIS VALUES TD

```
PLXY-11M SUBROUTINE LINE
         ! YP
                  = ARRAY USED TO PASS Y-AXIS VALUES TO
                    PLXY-11M SUBROUTINE LINE
        REAL LX, SX, IX, LY, SY, IY, LYS, XP(125), YP(125)
        REAL*8 LABEL(3), BREG(10)
         INTEGER PSYM(2), BR, ATT, COR
        BYTE DE, DP, RDU, REU, PRT
        COMMON /BODY/B(9,3), COR(9,2), WGT(12)
         1, /PROB/BR, ATT, RD, RDM, TA, NN, TDMS, DZ, DZV, FLAG3, RDS
        2, RDU
        3. /PLOT/P(125, 9), LX, SX, IX, LY, SY, IY, LYS, LABEL, NREC
         4, BREG, XP, YP, PD(125, 3), LCL, CH, REU, PRT(13)
        SL=3.0
         IF (CH. GT. O. O) SL=CH
        CALL SYMBOL (LX-SL, LYS-0, 20, 0, 1169, BREG(BR), 0, 0, +8)
         IF (IR. EQ. 1) GO TO 10
         CALL SYMBOL (999., 999., 0.1169, PRT, 0.0, +LCL)
10
        CALL PLOT (0.0,0,0,+3)
        LYS=LYS-0. 20
         IF (ATT. EQ. 2) RMD=RDM
         IF (ATT. EQ. 1) RMD=RDM+RDS+(B(BR, 3)/2.0)
         IF (ATT. NE. 0) GO TO 5
        RMD=RDM+RDS
         IF (BR. EQ. 4) RMD=RMD+(B(BR, 2)/2.0)
        IF (BR. NE. 4) RMD=RMD+(B(BR, 3)/2.0)
5
        DO 13 J=1,2
        L=O
        DO 12 K=1, NREC
         CHECKING EXP'T VALUE TO BE IN RANGE OF PLOT
         IF (P(K, 1+IR), LE. O. O. OR. P(K, 1+IR), LT. SY) GO TO 12
        L=L+1
         XP(L)=P(K,1)
        PD(L, 1) = XP(L)
         IF (IR. NE. 1) GO TO 11
         YP(L)=(P(K, J+IR)-P(K, 9))/(P(K, 8)-P(K, 9))
         PD(L, J+1)=YP(L)
         GO TO 12
11
         IF (IR. NE. 5) GO TO 12
         TM=(P(K, J+1)+P(K, 9))/2.0
         YP(L)=(P(K, J+IR)*(B(BR, 2))/2, 0)/TC(TM, RMD)
         PD(L, J+1)=YP(L)
12
         CONTINUE
         XP(L+1)=SX
         XP(L+2)=IX
         YP(L+1)=SY
         YP(L+2)=IY
         CALL PLOT (0, 0, 0, 0, +3)
         CALL LINE (XP, YP, L, 1, +1, PSYM(J))
         CALL SYMBOL (LX-SL, LYS-0. 20, 0. 1169, LABEL(J), 0. 0, +8)
         CALL WHERE (E,F,G)
         CALL SYMBOL (E,F+(0.1169/2.0), 0.1169, PSYM(J), 0.0, -1)
         CALL WHERE (E, LYS, G)
```

LYS=LYS-(0.1169/2.0)

13 CONTINUE

WRITE (6,14) (PD(K,1),PD(K,2),PD(K,3),K=1,L)

14 FORMAT (10X, FB. 2, 10X, F10. 2, 10X, F10. 2)

RETURN

END

APPENDIX G

SAMPLE CALCULATION '

To illustrate the computations performed by the interactive model program, an example will be calculated by hand and compared to the corresponding program output (Table G.1). Table G.2 is a question flow of the form introduced in the documentation section (Appendix D) which shows the responses to the program's queries necessary to generate the example program output (Table G.1).

The example output is generated in the research mode, yet Table G.1 is the output of a simple production mode run (See Table D.2.) with the addition of the program generated debug information. This mimicking of the production mode from the research mode is done to activate the debug prints which contain the results of the intermediate computations necessary for comparison.

The answers to questions 4 thru 8, 10, and 14 thru 17 of Table G.2 display the information necessary to define the example problem. These responses indicate that the modeled diver is lying prone (question 17) in a wet environment at a depth of 10.0 FSW (question 4) and at a temperature of 5.0 °C (question 15). The ensemble being worn is the U.S. Navy's prototype

Table G.1

A Production Mode Output Enhanced With Debug Information

BODY REGION: POSTURE: 0=SIT,1=STAND,2=PRONE DESIGN MEAN SKIN TEMPERATURE: REFERENCE DEPTH: AMBIENT TEMPERATURE:	30.00 C 30.00 FSW 5.00 C
PREDICTED TEMPERATURE FOR REGION 3: DZ,DZV 0.3530000 0.00000000	W/M**2*C 25 W/M**2 70 W/M**2 55 W/M**2 .35 WATTS .54 WATTS

Table G.2

Question Flow for Generation of Table G.1

Question #	Response
1	Y Y
2 3 4	Ý
	F10.0
5	X
6	X
7	X
8 9	X F
10	1
11	Ñ
12	NA
13	NA
14	30.0
15	5.0
16	3
17 18	2 NA
19	NA NA
20	NA NA
21	NA
22	NA
23	NA

diver thermal protection garment (questions 5 and 6). The calculations are to be performed only for the abdomen (question 16) and are assuming one node per region (question 10). The diver's mean skin temperature (question 14) is to be maintained at a steady value of 30.0 °C, and the values of allowable heat flux (question 7) and biasing factor (question 8) to be used are those assigned by the program.

The following array listings contain the information necessary to perform the example calculations. The arrays are displayed in the order of their use in the example calculations. Each array, which contains either regional or segmental data, is displayed with the region or segment ID numbers and names. Regional data corresponds to the nine regions of the model man (Fig. 1 of Chapter I) and segment data corresponds to the twelve Hody segments (Fig. 2 of Chapter I).

Array COR(9,2)

Region ID #	Region Name	Corresponding Segments	
		\$1	S2
1	HEAD	1	-1
2	TORSO	2	4
3	ABDOMEN	3	5
4	THIGH	8	10
5	CALF	9	11
6	FOOT	12	-1
7	UPPER ARM	6	-1
~ 8	LOWER ARM	6	-1
9	HAND	7	-1

Array COR indicates the correspondence between model regions and Hody segments. Note: A segment of -1 indicates that there is a one to one correspondence between a model region and a Hody segment.

Array KA(12)

Segment ID #	Segment Name	Predictive Skin Temperature Correlation Coefficient
1	HEAD	0.36
2	CHEST	0.27
3	ABDOMEN	0.30
4	UPPER BACK	0.52
5	LOWER BACK	-0.08
6	ARM	0.22
7	WRIST	-0.64
8	FRONT THIGH	-0.04
9	FRONT CALF	-0.16
10	REAR THIGH	-0.06
11	REAR CALF	-0.55
12	F00T	-0.86

Array KA contains the twelve segmental coefficients needed to use the predictive skin temperature correlation. The development of this correlation is described in Chapter IV.

Constant KR

Along with the twelve segment coefficients, the predictive skin temperature correlation requires a fixed constant KR.

KR = 2.946

This constant is also described in Chapter IV.

Array WGT(12)

Segment ID #	Segment Name	Hody Skin Surface Area Fraction
1	HEAD	0.070
2	CHEST	0.085
3	ABDOMEN	0.085
4	UPPER BACK	0.090
5	LOWER BACK	0.090
6	ARM	0.140
7	WRIST	0.050
8	FRONT THIGH	0.095
ğ	FRONT CALF	0.065
10	REAR THIGH	0.095
11	REAR CALF	0.065
12	FOOT	0.070

Array WGT contains the twelve Hody surface area fractions corresponding to the 12 segments (Fig. 2 of Chapter I).

Array C(6,7)

	Temperature (°F)					
Pressure (PSIA)	30.00	50.00	70.00	90.00	110.00	130.00
14.70	3.93	4.06	4.19	4.32	4.45	4.58
30.00	3.93	4.07	4.20	4.33	4.46	4.59
50.00	3.95	4.08	4.21	4.34	4.47	4.59
100.00	3.98	4.11	4.24	4.37	4.49	4.62
200.00	4.03	4.16	4.29	4.42	4.54	4.66

Array C contains values of the thermal conductivity of air multiplied by 10^{+6} as a function of temperature (°F) and absolute pressure (PSIA).

Garment Ensemble Constants

WUGO: 1.63 (CM)
SRO: 2.27 (CLO/CM)
DR: 0.1175
WOG: 0.15875 (CM)
COG: 0.17307 (W/M°C)

WUGO = Unit thickness of undergarment at sea level

SRO = Specific thermal resistance of undergarment at sea level

- DR = Ratio of the decimal percent change in specific thermal resistance (SRO) to the decimal percent change in thickness of the undergarment. This is the slope of a line which describes the change in the undergarment specific thermal resistance with a change in the undergarment thickness due to a hydrostatic pressure differential between the inside and the outside of the ensemble. (See Fig. 68 of Chapter V.)
- WOG = Width of the outer garment. This value is constant over all temperatures and pressures due to the impermeability and incompressibility of the outer garment material.
- COG = Thermal conductivity of outer garment. This value is constant over all gases due to the impermeability of outer garment material.

Array TWUGO(9)

Region Region ID # Name		Number of Layers of Undergarment WUGO Thick		
1	HEAD	1.0		
2	TÓRSO	1.0		
3	ABDOMEN	1.0		
4	THIGH	1.0		
5	CALF	1.0		
6	F00T	2.0		
7	UPPER ARM	1.0		
8	LOWER ARM	1.0		
9	HAND	1.0		

Array TWUGO defines the number of layers of unit thickness undergarment material covering each region.

Array B(9,3)

Region ID #	Region Name	Shape <u>Indicator</u>	Major <u>Diameter</u>	Characteristic Length
1	HEAD	-1.000	0.206	0.206
2	TORSO	0.000	0.300	0.353
3	ABDOMEN	0.000	0.300	0.353
4	THIGH	0.000	0.150	0.383
5	CALF	0.000	0.120	0.328
6	FOOT	0.000	0.150	0.104
7	UPPER ARM	0.000	0.096	0.223
8	LOWER ARM	0.000	0.070	0.267
9	HAND	-1.000	0.123	0.123

Array B contains the body dimensions of the nine region model man (Fig. 1 of Chapter I).

Shape indicator: -1.0 = sphere

0.0 = cylinder

Major diameter: For sphere and cylinder - the diameter Characteristic Length: For sphere - same as major diameter For cylinder - the length of cylinder

Array BF(9)

Region ID #	Region Name	Empirically Derived Biasing Factor
1	HEAD	2.63
2	TORSO	2.63
3	ABDOMEN	2.27
4	THIGH	3.50
5	CALF	3.21
6	F00T	12.70
7	UPPER ARM	2.29
8	LOWER ARM	2.19
9	HAND	3.49

Array BF defines the empirically derived biasing factors used to correct the predicted overall heat transfer coefficients (OHTC). The derivation of these biasing factors may be found in Chapter VII.

Array SAM(9)

Region ID#	Region Name	Regional Surface Area (M ²)
1	HEAD	0.1333
2	TORSO	0.3327
3	ABDOMEN	0.3327
4	THIGH	0.3610
5	CALF	0.2474
6	F00T	0.1334
7	UPPER ARM	0.1490
8	LOWER ARM	0.1174
9	HAND	0.0950

Array SAM contains the nine regional surface areas computed from the dimensions described in Array $\ensuremath{\text{B}_{\bullet}}$

Array QALL(9)

Region ID #	Region Name	Allowable Heat Flux (W/M ²)
1	HEAD	23.30
2	TORSO	60.00
3	ABDOMEN	49.70
4	THIGH	42.40
5	CALF	85.00
6	FOOT	97.00
7	UPPER ARM	98.90
8	LOWER ARM	125.25
9	HAND	265.86

Array QALL contains the allowable regional heat fluxes necessary to remove the waste heat produced by a resting seated subject. These were extracted from data by Burriss $\underline{\text{et al.}}$ [33,34].

The computations which appear on the following pages were performed to check the computational accuracy of the interactive model program's algorithm, as well as to provide a sample to illustrate the calculation of the predicted heat loss values. To facilitate this checking of the program's algorithm, the hand calculations maintain more significant figures than would be expected from the accuracy of the experimental data from which the diver heat loss model was developed.

Begin Sample Computations

```
In the Main module:
Calculate regional skin temperature (T1).
Given: Design mean skin temperature (TDMS) = 30.0°C
        Body region (BR) = 3 (Abdomen)
T1 = TR(TDMS,BR)
From Function TR:
  From Array COR for BR = 3:
    COR(3,1) = 3 (Hody's site 3) = S1
    COR(3,2) = 5 (Hody's site 5) = S2
TR(TDMS,3) = \frac{PRED(S1,TDMS)}{PRED(S1,TDMS)} \cdot WGT(S1) + PRED(S2,TDMS) \cdot WGT(S2)
                               WGT(S1) + WGT(S2)
  From Function PRED:
    PRED(S,TDMS) = TDMS + KA(S) \cdot KR
    PRED(S1,TDMS) = 30.0 + KA(3) \cdot KR
      KR = 2.946
      From Array KA for site 3:
      KA(3) = 0.30
    PRED(S1,TDMS) = 30.0 + (0.30)(2.946) = 30.88 °C
    PRED(S2, TDMS) = 30.0 + KA(5) \cdot KR
      KR = 2.946
      From Array KA for site 5:
      KA(5) = -0.08
    PRED(S2,TDMS) = 30.0 - (0.08)(2.946) = 29.76 °C
  From Array WGT for sites 3 and 5:
    WGT(3) = 0.085
    WGT(5) = 0.090
TR(TDMS,3) = \frac{(30.88 \cdot 0.085) + (29.76 \cdot 0.090)}{}
                        (0.085 + 0.090)
```

T1 = 30.308 °C

In this example, calculations are shown for a single node per region; if multiple nodes were desired, the following would be executed once for each node.

Begin multiple node loop:

Calculate the overall heat transfer coefficient (OHTC).

Using: Subroutine OHTC

Given: Design mean skin temperature (TDMS) = 30.0 °C

Body region (BR) = 3 (Abdomen) Diver's posture (ATT) = 2 (Prone)

Depth below sea level of shoulders (RD) = 10.00 FSW

Ambient temperature (TA) = 5.0 °C

Regional skin temperature (T1) = 30.308 °C

$$OHTC = \frac{1.0}{RUG + ROG + ROBL}$$

RUG = Unit thermal resistance of the undergarment as a function of the ambient temperature and depth, and the hydrostatic pressure differential due to the region's depth below the shoulders.

ROG = Unit thermal resistance of the outer garment. The outer garment is assumed to be unaffected by the suit entrapped gas (impermeable) and the hydrostatic pressure difference (incompressible).

ROBL = Unit thermal resistance of the outer fluid boundary layer. This is predicted by using empirically derived equations fitted to experimental data.

Determine RUG:

$$RUG = \frac{RUGHAJ \cdot R1 \cdot 1n^{\dagger} (R2/R1) \cdot 100.0}{WUGO \cdot TWUGO(BR) \cdot (1.0 - DPCT)}$$

Determine unit thermal resistance of a flat undergarment sample at depth (RUGHAJ).

Determine the thermal conductivity ratio (CR).

CR is the ratio of the thermal conductivity of air at sea level and standard temperature, and the thermal conductivity of the suit entrapped gas at ambient depth and temperature.

[†]In implies logarithm to the base e.

When the suit entrapped gas is air,

$$CR = \frac{TC(21.1,0 \text{ MSW})}{TC(MT,EDS)}$$

EDS = Element (node) depth below sea level = RDM + RED

RDM = Reference depth (RD) converted to MSW For RD given as 10.0 FSW,

 $RDM = 10.00 FSW \cdot 0.3048 \frac{MSW}{FSW}$

RDM = 3.048 MSW

RED = Regional element (node) depth below the shoulder reference.

This depth is computed to the mid-point of the nodal element and indicates the hydrostatic pressure differential.

For a diver posture (ATT) = 2 (Prone),

RED = 0.0, since all regions are at the same depth below sea level.

EDS = 3.048 + 0.0EDS = 3.048 MSW

MT = Mean temperature of the suit entrapped gas

MT = (T1 + TA)/2.0

MT = (30.308 + 5.0)/2.0

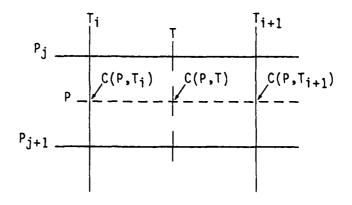
MT = 17.65 °C

$$CR = \frac{TC(21.1,0)}{TC(17.65,3.048)}$$

From Function TC(TDC,Z): Convert TDC (°C) to T (°F), T (°F) = ((TDC + 273.15) • 1.8) - 459.67

Convert Z (MSW) to P (PSIA), P (PSIA) = $(Z \cdot 100.0 \cdot 64.15)/(2.54 \cdot 12.0^3) + 14.7$

Using a method of two-dimensional linear interpolation (Adapted from Carnahan, Luther, and Wilkes, <u>Applied Numerical Methods</u>, p. 63, Problem 1.28 [49], Function TC estimates the value of the thermal conductivity of air from Array C. This method is outlined on the next page.



$$\begin{split} & C(P,T) = C(P,T_{i}) + \left(C(P,T_{i+1}) - C(P,T_{i})\right) \cdot \beta \\ & C(P,T_{i}) = C(P_{j},T_{i}) + \left(C(P_{j+1},T_{i}) - C(P_{j},T_{i})\right) \cdot \alpha \\ & C(P,T_{i+1}) = C(P_{j},T_{i+1}) + \left(C(P_{j+1},T_{i+1}) - C(P_{j},T_{i+1})\right) \cdot \alpha \\ & \text{where:} \quad \beta = (T - T_{i})/(T_{i+1} - T_{i}) \\ & \alpha = (P - P_{j})/(P_{j+1} - P_{j}) \end{split}$$

Determine TC(21.1,0).

TDC = 21.1 °C ,
$$Z = 0$$
 MSW $T = 69.98$ °F , $P = 14.7$ PSIA

$$C(P,T) = 4.1899 \times 10^{-6} BTU/SEC FT^{\circ}F$$

Convert C(P,T) in BTU/SEC FT°F to W/M°C

$$C(P,T) = 4.1899 \times 10^{-6} \cdot 6230.551 \frac{W/M^{\circ}C}{BTU/SEC \cdot FT^{\circ}F}$$

$$TC(21.1,0) = 2.6105 \times 10^{-2} \text{ W/M}^{\circ}\text{C}$$

Determine TC(17.65,3.048).

TDC = 17.65 °C ,
$$Z = 3.048$$
 MSW $T = 63.77$ °F , $P = 19.155$ PSIA

$$C(P,T) = 4.1524 \times 10^{-6} BTU/SEC-FT^{\circ}F$$

Convert C(P,T) in BTU/SEC FT°F to W/M°C

$$C(P,T) = 4.1524 \times 10^{-6} \cdot 6230.551 \frac{W/M^{\circ}C}{BTU/SEC \cdot FT^{\circ}F}$$

$$TC(17.65, 3.048) = 2.5872 \times 10^{-2} \text{ W/M}^{\circ}\text{C}$$

$$CR = \frac{TC(21.1,0)}{TC(17.65,3.048)}$$

$$CR = \frac{2.6105 \times 10^{-2}}{2.587.2 \times 10^{-2}}$$

CR = 1.009006

Determine specific thermal resistance of the undergarment in the ambient environment (SRUGA).

The specific thermal resistance of the undergarment material at sea level in air (SRO) is adjusted for the effects of the suit entrapped gas at ambient conditions through multiplication by the conductivity ratio (CR).

SRUGA = SRO • CR SRUGA = 2.27 CLO/CM • 1.00901 SRUGA = 2.29044 CLO/CM

Determine the decimal percent change in undergarment thickness (DPCT) due to hydrostatic pressure (RED in CM).

```
For RED \leq 0.1711 CM:

DPCT = RED • 100.0 • 2.358 × 10<sup>-2</sup>

For RED > 0.1711 CMS:

DPCT = 0.343 + (RED • 100.0 • 3.784 × 10<sup>-3</sup>)

- ((RED • 100.0)<sup>2</sup> • 1.345 × 10<sup>-5</sup>)
```

As previously stated for a prone diver, RED = 0.0 since all regions are at the same depth below sea level.

DPCT =
$$0.0 \cdot 100.0 \cdot 2.358 \times 10^{-2}$$

DPCT = 0.0

Determine the specific thermal resistance of the undergarment at ambient conditions corrected for the effects of hydrostatic pressure (SRUGHA).

SRUGHA is formed by multiplying the specific thermal resistance of the undergarment (SRUGA) by one minus the decimal percent change in specific thermal resistance due to a change in undergarment thickness (DPCT • DR).

SRUGHA = SRUGA • (1.0 - DPCT • DR) SRUGHA = 2.29044 • (1.0 - 0.0 • 0.1175) SRUGHA = 2.29044 CLO/CM Determine the unit thermal resistance (RUGHA).

The specific thermal resistance (SRUGHA) is converted to a unit thermal resistance (RUGHA) by multiplying by the actual thickness of the undergarment.

RUGHA = SRUGHA • (WUGO • TWUGO(BR))(1.0 - DPCT)

From Array TWUGO:

TWUGO(3) = 1.0

WUGO = 1.63 CM

DPCT = 0.0

RUGHA = $2.29044 \cdot (1.63 \cdot 1.0)(1.0 - 0.0)$

RUGHA = 3.7334 CLO

Convert undergarment resistance in CLO (RUGHA) to $M^2 \circ C/W$ (RUGHAJ).

 $RUGHAJ = RUGHA \cdot 0.15477 \frac{M^2 \circ C/W}{GLO}$

RUGHAJ = $0.57782 \, \text{M}^2 \, \text{C/W}$

Determine radius from center line of region to skin surface (R1).

R1 = B(BR,2)/2.0 = B(3,2)/2.0

From Array B: B(3,2) = 0.300 M

D1 - 0 200/2 0

R1 = 0.300/2.0R1 = 0.15 M

Determine radius from center line to outer surface of undergarment (R2).

 $R2 = R1 + (WUGO \cdot TWUGO(BR) \cdot (1.0 - DPCT)/100.0)$

From Array TWUGO:

TWUGO(3) = 1.0

 $R2 = 0.15 + (1.63 \cdot 1.0 \cdot (1.0 - 0.0)/100.0)$

R2 = 0.1663 M

etermine radius from center line to outer surface of outer garment (R3).

+1 + 406/100.0 | ++1 + 10.15875/100.0) Determine the unit thermal resistance of the undergarment on a cylindrical surface (RUG) by converting the unit resistance on a flat surface (RUGHAJ).

$$RUG = \frac{RUGHAJ \cdot R1 \cdot ln (R2/R1) \cdot 100.0}{WUG0 \cdot TWUG0(BR) \cdot (1.0 - DPCT)}$$

$$RUG = \frac{0.57782 \cdot 0.15 \cdot ln (0.1663/0.15) \cdot 100.0}{1.63 \cdot 1.0 \cdot (1.0 - 0.0)}$$

$$RUG = 0.548529 M2 \circ C/W$$

Determine ROG:

$$ROG = \frac{R1 \cdot ln (R3/R2)}{COG}$$

$$ROG = \frac{0.15 \cdot ln (0.1678875/0.1663)}{0.17307}$$

$$ROG = 8.23429 \times 10^{-3} M^{2} \cdot C/W$$

Determine ROBL for water boundary layer:

$$ROBL(T3) = \frac{R1}{R3 \cdot CHTC(T3,R3)}$$

Determine the temperature of outside surface of the outer garment (T3) by application of the Secant Method for finding the roots of the equation displayed below and coded as Function F(T).

$$F(T3) = \frac{T1 - TA}{RUG + ROG + ROBL(T3)} - \frac{T1 - T3}{RUG + ROG}$$

Repeated solutions of the above with the Secant algorithm to select the new estimates of T3 yielded F(T3) = 0 when T3 = 5.7194 °C.

Determine the convective heat transfer coefficient (CHTC(T3,R3)).

Given: Diver posture (ATT) = 2 (Prone)
Body region (BR) = 3 (Abdomen)
Temperature of outer surface (T3) = 5.7194 °C
Ambient temperature (TA) = 5.0 °C
Radius to outer edge of garment (R3) = 0.1678875 M

Determine the Grashof Prandtl number product (GrPr).

$$GrPr = \alpha \cdot CL^3 \cdot (T3 - TA)$$

Determine
$$\alpha = \frac{g\beta\rho^2Cp}{\mu k}$$

$$\log^{\dagger} \alpha = 9.80714 (\log T_f)^{0.12733}$$

This equation fits data taken from Holman [40] over a range of temperatures from 4.44 °C to 21.11 °C for α in units of 1/(M³°C).

Determine film temperature (T_f) .

$$T_f = (T3 + TA)/2.0$$

 $T_f = (5.7194 + 5.0)/2.0$
 $T_f = 5.3597$ °C

log
$$\alpha = 9.80714 (\log T_f)^{0.12733}$$

log $\alpha = 9.80714 (\log 5.3597)^{0.12733}$
log $\alpha = 9.4205$

$$\alpha = 10^{\log \alpha} = 10^{9.4205}$$

 $\alpha = 2.6333 \times 10^{+9} 1/(M^{3} \text{ C})$

Determine characteristic length (CL).

For diver posture (ATT) = 2, body region (BR) = 3 is classified as a horizontal cylinder. For a horizontal cylinder the characteristic length (CL) is defined to be the overall diameter of the cylinder which includes the garment ensemble.

GrPr =
$$\alpha \cdot CL^3 \cdot (T_3 - T_4)$$

GrPr = $2.6333 \times 10^{+9} (0.335775)^3 \cdot (5.7194 - 5.0)$
GrPr = $7.17160 \times 10^{+7}$

[†]log implies logarithm to the base 10.

Determine Nusselt number.

Given: Horizontal cylinder (BR = 3 and ATT = 2)

For a horizontal cylinder, log Nu = 0.2486 (log GrPr) - 0.4483

This equation fits experimental data taken during a series of respiratory heat loss studies performed by the Navy Experimental Diving Unit. (See Chapter II.)

 $log Nu = 0.2486 (log 7.1716 \times 10^{+7}) - 0.4483$ log Nu = 1.5046

 $Nu = 10^{1} \text{ og } Nu = 10^{1.5046}$ Nu = 31.9595

Determine convective heat transfer coefficient (h).

$$h = \frac{Nu \cdot k}{Cl}$$

Determine thermal conductivity (k).

 $k = 1.7977 \times 10^{-3} (T_f) + 0.56662$

This equation fits data taken from Holman [40] over a range of temperatures from 0 °C to 21.11 °C for k in units of W/M°C.

 $k = 1.7977 \times 10^{-3} (5.3597) + 0.56662$ $k = 0.57626 \text{ W/M}^{\circ}\text{C}$

$$h = \frac{31.9595 \cdot 0.57626}{0.3357750}$$

h = 54.8492

CHTC(T3,R3) = h = 54.8492

$$ROBL(T3) = \frac{R1}{R3 \cdot CHTC(T3,R3)}$$

$$ROBL(T3) = \frac{0.15}{(0.1678875)(54.8492)}$$

$$ROBL(T3) = 1.629 \times 10^{-2} M^{2} \circ C/W$$

$$HTC = \frac{1.0}{RUG + ROG + ROBL}$$

OHTC =
$$\frac{1.0}{0.548529 + 8.23429 \times 10^{-3} + 1.629 \times 10^{-2}}$$

OHTC = $1.74504 \text{ W/M}^{2} \text{ °C}$

Return to Main program.

Since this is a production mode run, the regional/nodal OHTC's are corrected by applying empirically derived biasing factors.

Determine corrected value of overall heat transfer coefficient (U).

$$U = OHTC \cdot BF(BR)$$

From Array BF for region 3: BF(3) = 2.27

 $U = OHTC \cdot BF(3)$

 $U = 1.74504 \cdot 2.27$

 $U = 3.96124 \text{ W/M}^2 \circ \text{C}$

To allow for multiple nodes per region add the most recent nodal U into a regional sum (US) and increment a nodal counter (UN).

US = US + U

US = 3.96124

UN = UN + 1.0

UN = 1.0

Determine a nodal heat flux (QR).

 $QR = U \cdot (T1 - TA)$

 $QR = 3.96124 \cdot (30.308 - 5.0)$

 $QR = 100.2511 \text{ W/M}^2$

Determine a nodal heat loss (Q).

 $Q = QR \cdot SAM(BR)/NN$

From Array SAM for region 3: $SAM(3) = 0.3327 M^2$

In this example NN = 1 since there is only one node per region. In a multi-node case NN would contain the number of nodes per region.

 $0 = 100.2511 \cdot 0.3327/1.0$

0 = 33.3535 W

Determine the total regional rate of heat loss Q(BR) as of this node.

Q(BR) = Q(BR) + Q Q(BR) = 0.0 + 33.3535Q(BR) = 33.3535

The array Q is used to store the regional rate of heat loss to allow a complete regional rate of heat loss record to be kept if all nine regions are being done at once. (A '0' (zero) response to question 16 of Table G.2.)

At this point all computations for a particular node have been completed. Thus if multiple nodes per region are being done, the calculations for the overall heat transfer coefficient (OHTC) must be repeated for the next node.

Begin new nodal loop.

When all nodes are calculated:

Determine the average regional overall heat transfer coefficient (U).

U = US/UN
U = 3.96124/1.0
U = 3.96124 W/M²°C

Corrected Predicted OHTC for Region 3: 3.96124 W/M²°C

Determine regional heat flux Q(BR).

Q(BR) = Q(BR)/SAM(BR)
Q(BR) = 33.3535/0.3327
Q(BR) = 100.2510 W/M²

Predicted Unit Heat Flux for Region 3: 100.2510 W/M²

From Array QALL for region 3: QALL(3) = 49.70 W/M²

Allowable Unit Heat Flux for Region 3: 49.70 W/M²

Determine supplementary heat flux (QSUPP(BR)).

QSUPP(BR) = Q(BR) - QALL(BR) QSUPP(BR) = 100.2510 - 49.70 QSUPP(BR) = 50.5510 W/M²

Required Supplementary Heat Flux: 50.551 W/M²

Determine regional rate of heat loss (QP).

QP = Q(BR) • SAM(BR) QP = 100.2510 • 0.3327 QP = 33.3535 W

Predicted Heat Loss for Region 3: 33.3535 W

Determine regional rate of allowable heat loss (QA).

QA = QALL(BR) • SAM(BR) QA = 49.70 • 0.3327 QA = 16.535 W

Allowable Heat Loss for Region 3: 16.535 W

Determine supplementary heating requirement (QSUP).

QSUP = QP - QA

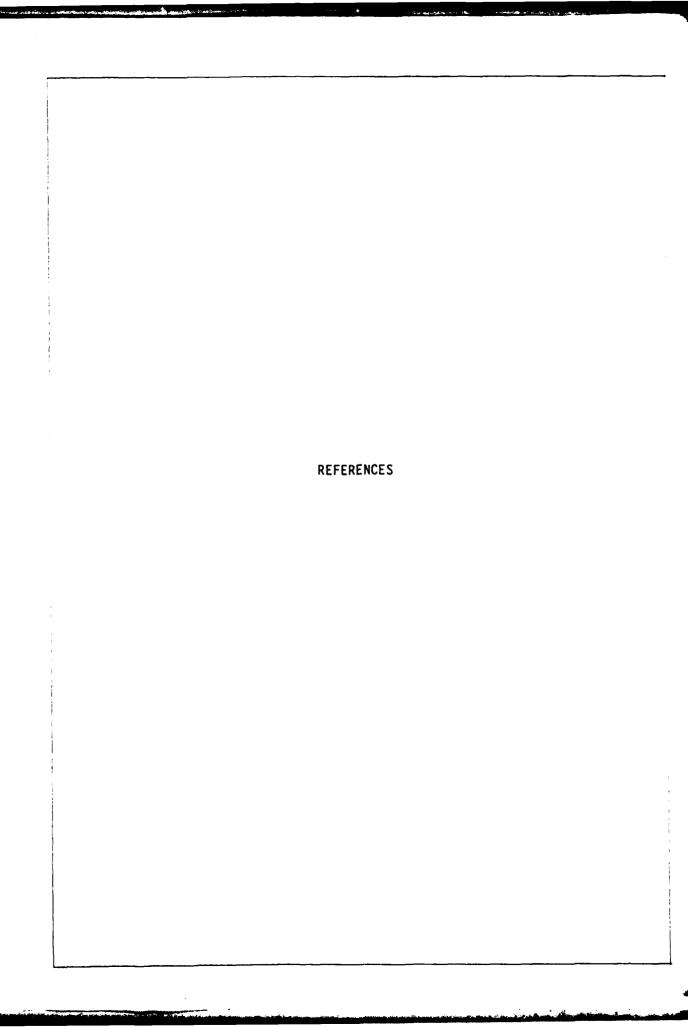
QSUP = 33.3535 - 16.535

OSUP = 16.8185 W

Required Supplementary Heating: 16.8185 W

At this point the calculations are complete. If another case were desired, one must define a new set of constraints by selecting the appropriate answers to the questions of Table G.1.

Comparison of the hand computed variables with the corresponding variables of Table G.1 indicates that the computer solution and the hand calculation agree to within at least three significant digits. This indicates the accuracy of the computer solution. The items in Table G.1 that do not appear in the hand calculations are either pertinent only with non-prone subjects or pertain solely to the execution of the Secant algorithm.



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ADDENDUM: MIXED BREATHING GAS INTERACTIVE MODEL PROGRAM:

to

Technical Report

THE DEVELOPMENT OF PREDICTIVE ENGINEERING FORMULATIONS FOR DIVER HEATING

bу

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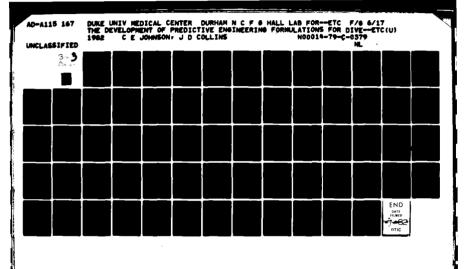
for

Naval Medical Research and Development Command

and

Office of Naval Research

1982



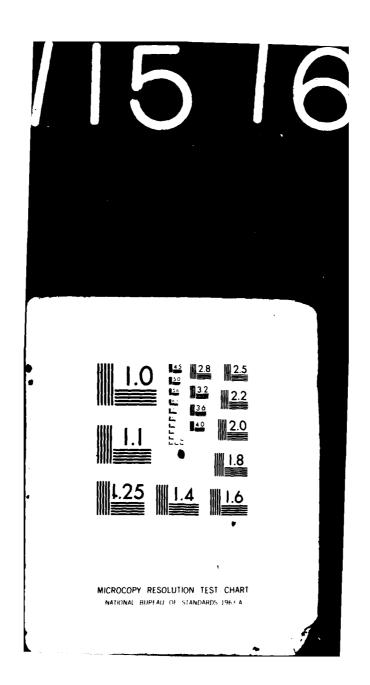


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MIXED BREATHING GAS INTERACTIVE MODEL PROGRAM DESCRIPTION

This addendum to The Development of Predictive Engineering Formulations for Diver Heating discusses the modification of the air diving program to permit the estimation of supplementary heating requirements when mixed breathing gas is employed with a pressure compensated dry suit. We will discuss only the specific changes to the numerical model code that were necessary to perform mixed gas related calculations. The remainder of the numerical code is exactly as previously presented in the main report. We also will present a listing of the twelve modules constituting the mixed breathing gas executable program titled MGMOD.TSK, a revised flow chart of the real function subroutine thermal conductivity (TC) which was adapted to accommodate both nitrogen-oxygen and helium-oxygen mixtures, a flow chart of the new function subroutines TCMG and INTERP associated with TC, and a description of the overlay structure required to build this program under DEC's RSX-11M operating system. Although this numerical code was developed for a binary mixture of nonpolar gases, the predictive program and subroutines could be easily adapted to accommodate tertiary mixtures of nitrogen, helium, and oxygen, whose use is being explored experimentally for very deep diving.

Our present mixed gas program is limited to the 1 to 69 ATA pressure range and the -1 to 54 °C temperature range by the data arrays compiled within the real function subroutine INTERP. It is our opinion that gas mixture predictive correlations for pressure and temperature should be experimentally validated prior to assuming accurate prediction of properties beyond the ranges cited.

There is currently no available mixed gas experimental data analogous to that which was collected during the Diver Thermal Protection series and which was used in our major report; however, we consider that MGMOD.TSK will predict supplementary heating requirements for resting divers who are breathing mixed gas with an accuracy comparable to that obtained with HLMOD.TSK. We express this opinion because the only change to the major program logic is the consideration of the effect of mixed gas permeating the open cell insulative undergarment. We note on page 142 of the report that the tests of Nuckols [1] indicated that the insulative properties of diver undergarment materials can be attributed primarily to their ability to entrap gas. Nuckols found in a normal environment that the thermal resistance of a porous material was proportional to the gas thermal conductivity with which it was permeated. The laws of physics permitted us to extrapolate these findings to the ambient conditions of diving with either pressurized air or mixed gas.

Referring to the listing of the Main module MHLMOD.FTN, the first variation from the original program HLMOD.FTN is the introduction of two variables in the main program labeled COMMON/TRNOSQ/ statement. YG is a real variable which is used to quantify the mole fraction of the inert gas component of a binary breathing mixture. IG is a byte data type variable employed to identify the inert gas component of a mixture or air. Inert gases considered in this program are nitrogen and helium, and the symbols used in the program are 'N' and 'H', respectively. 'A' is used to designate air. The

second modification to the Main module is the introduction of two additional interactive questions seen on page 388 of the program listing. Referring to Appendix E, Interactive Program Flow Chart, these two questions would be labeled 4a and 4b, respectively, and would be interjected between questions labeled 4 and 5 on page 270.

- 4a Select breathing gas:
 (A)ir or oxygen mixed with (H)elium
 or (N)itrogen.
- 4b Enter mole fraction of inert component.

Similarly, questions 4a and 4b would be inserted immediately before question 5 on page 220 of Appendix D, Interactive Program Documentation. There are no other changes to the Main module. Further modifications which are necessary to apply the model for mixed gas breathing are contained within the associated subroutine modules. We suggest that the reader refer to the module listing of MHLMOD.FTN and the cited subroutine modules in order to understand the program logic that now will be described. The program listing begins on page 381.

We see on page 393 of the program listing that statement label 118 determines the regional overall heat transfer coefficient U by means of the Function OHTC. Reviewing the real function subroutine OHTC, we see that it is necessary to compute the conductivity ratio CR defined as

$$CR = TCAR/TC(MT, EDS)$$
 (1)

in order to correct the undergarment reference specific thermal resistance for the effects of entrapped gas at the ambient temperature and pressure. The variable MT is the estimated temperature of the gas entrapped in the undergarment and EDS is the depth below sea level of the differential element of a body region that is being considered. (See Fig. 72, page 155, for

illustration of such a differential element.) The expression TC(MT,EDS) calls the real function subroutine TC. TCAR is the reference value for the thermal conductivity of air at 21.1 °C and 0.0 meters depth. This reference value of undergarment thermal conductivity is used whether the breathing gas is air or a binary mixture.

The called function subroutine TC also accesses the variables YG and IG as specified in the labeled COMMON/TRNOSQ/ statement. Using IG, the function subroutine TC determines whether the ambient gas is air or a mixture. If IG is 'A', the routine proceeds exactly as explained in the main report and calculates the thermal conductivity of air at the ambient conditions. However, if IG is either 'N' or 'H', the subroutine calls the real function subroutine TCMG. The statement labeled 100 of the TC routine accesses the thermal conductivity-mixed gas function TCMG which calculates the mixture thermal conductivity as a function of the inert gas mole fraction, temperature, and pressure.

The values of ambient temperature (°F) and pressure (PSIA) are passed to TCMG by the function call of statement 100 as discussed above. The assigned values of YG and IG are again transferred by means of a block COMMON statement. The real function subroutine INTERP is called from within Function TCMG to calculate the values of thermal conductivity and viscosity for component gases of the mixture. Real function INTERP interpolates pure gas property data excerpted from the <u>U.S. Navy Diving Gas Manual</u> [2] as a function of temperature and pressure. Data of thermal conductivity and viscosity for nitrogen, helium, and oxygen are stored in INTERP. The interpolation algorithm is again that of Carnahan, Luther, and Wilkes [3]; see page 295 of the report. Using the interpolated pure component values now stored in Array TP, Function TCMG computes the mixed gas thermal conductivity by the Mason-Saxena form of Wassiljewa's equation as is recommended by

reference 4. This computed value of thermal conductivity for a mixed gas at ambient conditions is returned to Function OHTC where it is used to calculate the conductivity ratio CR, Equation 1. The remainder of the OHTC function subroutine performs as previously described in the main report and computes the value of U for the Main module.

The U.S. Navy Diving Gas Manual [2] tabulates the thermal conductivity of helium-oxygen gas mixtures as a function of temperature only at 1 ATA. The same is true for the absolute viscosity of helium-oxygen mixtures, but this principal reference contains no tabulations of thermal conductivity or absolute viscosity for nitrogen-oxygen mixtures. Appendix C of the U.S. Navy Diving Gas Manual implies that the limited data that is tabulated for thermal conductivity of helium-oxygen mixtures at low pressure were determined experimentally by Srivastava and Barua [5] and that the low pressure absolute viscosity of these mixtures were estimated by the Wilke technique. A description of Wilke's correlation may be found in reference 6. The U.S. Navy Diving Gas Manual does tabulate, from a number of reliable references, the thermal conductivity and absolute viscosity of nitrogen, helium, and oxygen as a function of temperature and pressure. The availability of this pure gas data permits reasonably accurate estimation of mixture values of thermal conductivity by means of the Wassiljewa equation that was discussed in Appendix C of our major report. Following the recommendation of Reid, Prausnitz, and Sherwood [4], we employ the Mason-Saxena form of Wasseljewa's equation. This form is similar to that previously presented as Equation C.7 except that the $\phi_{i,j}$ terms, defined below, have been substituted for the $A_{i,j}$

terms in Equation C.7. The equation for a binary mixture of inert gas and oxygen is:

$$k_{m} = \frac{k_{1}}{1 + 1.065 \, \phi_{12} \, (y_{2}/y_{1})} + \frac{k_{2}}{1 + 1.065 \, \phi_{21} \, (y_{1}/y_{2})} \tag{2}$$

where: k_m = Thermal conductivity of the binary mixture

 k_1, k_2 = Thermal conductivity of the pure components

 y_1, y_2 = Mole fraction of pure components

Subscript 1 identifies the inert gas component of the mixture and subscript 2, the oxygen component.

The ϕ_{ij} terms of Equation 2 are represented as:

$$\Phi_{12} = \left[\frac{1 + \left(\frac{\mu_1}{\mu_2}\right)^{.1/2} + \left(\frac{M_2}{M_1}\right)^{1/4}}{\left[8 + \left(\frac{M_1}{M_2}\right)^{.1/2}\right]^{1/2}} \right]$$
(6)

where: μ_1, μ_2 = Absolute viscosity of pure components M_1, M_2 = Molecular weight of pure components

By reciprocity, ϕ_{21} may be determined with ϕ_{12} and associated pure component properties.

$$\Phi_{21} = \left(\frac{\mu_2}{\mu_1}\right) \left(\frac{M_1}{M_2}\right) \Phi_{12} \tag{4}$$

The Mason-Saxena form of Wassiljewa's equation may be extended easily to the case of a tri-mixture of breathing gases, such as helium, nitrogen, and oxygen, by evaluating the general form of the equation:

$$k_{m} = \sum_{i=1}^{3} \frac{k_{i}}{1 + \sum_{\substack{j=1 \ i \neq i}}^{3} 1.065 \, \phi_{ij} \, (y_{j}/y_{i})}$$
 (5)

where:

$$\Phi_{ij} = \frac{\left[1 + \left(\frac{u_i}{u_j}\right)^{1/2} + \left(\frac{M_j}{M_i}\right)^{1/4}\right]^2}{\left[8 + \left(1 + \left(\frac{M_i}{M_j}\right)^{1/2}\right)^{1/2}}$$
(6)

When the indices i and j have been assigned specific values, a reciprocity relationship may be used to determine ϕ_{jj} in terms of ϕ_{ij} :

$$\Phi_{jj} = \left(\frac{\mu_{j}}{\mu_{i}}\right) \left(\frac{M_{i}}{M_{j}}\right) \Phi_{ij}$$
 (7)

To test the accuracy of our numerical algorithm of the Mason-Saxena form of Wassiljewa's equation, it was only possible to compare estimated and tabulated gas mixture thermal conductivity values at 1 ATA and a specific temperature. This was because of the discussed limitations of reference 2. A test comparison for a 95% helium - 5% oxygen mixture at 1 ATA and 21 °C (70 °F) revealed less than a 2% difference when the tabulated value was used as the comparative base. This small percent deviation is comparable

to the range of accuracy, for the computational Equation 5, cited both by Reid and Sherwood [6] and Reid, Prausnitz, and Sherwood [4]. Also, our computed thermal conductivity values for a binary mixture of helium and oxygen at elevated pressures compared quite favorably with values computed by Equation C.7.

PROGRAM LISTING (381)

```
MHLMOD (Main Module)
        REAL KA, KR, COG, G(10), EXP(29), SCALY(3, 3), SCALYN(2, 3)
        1, LX, SX, IX, LY, SY, IY, LYS, XP(125), YP(125)
        2, BF(9), QA(9), QP(9), QSUPP(9), SAM(9), QALL(9)
        REAL*8 LABEL(3), BREG(10)
        INTEGER FLAG1, FLAG2, COR, BR, ATT, SYM(2)
        BYTE RDU, QCOMP, FILE (30), WG, PLD, PLN, DUM, REU, NST
        1, PRTL(11), PRT, OUT, PU(2)
        COMMON /PREDD/KA(12), KR
        1, /BODY/B(9, 3), COR(9, 2), WGT(12)
        2,/TRNDSQ/YG,IG
        3,/SUIT/WUGO, DR, SRO, WDG, CDG, TWUGO (9)
        4,/DEBUG/FLAG2,LO
        5,/OHTCD/RUGHA, RUG, ROG, ROBL, R1, R2, R3, T1, T3, FLAG1
        6, Q1A, Q13
        7, /PROB/BR, ATT, RD, RDM, TA, NN, TDMS, DZ, DZV, FLAG3, RDS
        8, RDU
        9, /PLOT/P(125, 9), LX, SX, IX, LY, SY, IY, LYS, LABEL, NREC
        1, BREG, XP, YP, PD(125, 3), LCL, CH, REU, PRT(13)
        2,/MISC/GALL,BF
C*******************************
      NOTE: ALL VALUES FOR ARRAYS ENTERED VIA DATA STATEMENTS
            ARE ENTERED IN COLUMN MAJOR ORDER!!
    *******************************
C
        ARRAY B - CONTAINS REGIONAL BODY DIMENSIONS
                  *NOTE* ALL VALUES ARE IN METERS
                - 1ST COLUMN CONTAINS IDENTIFICATION OF SHAPE
                       -1 IMPLIES SPHERE
                        O IMPLIES CYLINDER
                       +# IMPLIES CONIC = DIAMETER OF TOP OF CONE
                  2ND # IS DIAMETER OF SPHERE, CYLINDER OR
                       BOTTOM OF CONE
                 - 3RD # IS THE HEIGHT OF REGION
        !DIMENSIONAL NUMBERS ENTERED FOR MODEL MAN
        !*NOTE* ALL CYLINDERS AND CONES ARE CONNECTED END
                TO END.
                 ID# - REGION = SHAPE / ENTERED #'S /
                 1 - \text{HEAD} = \text{SPHERE} / -1.0, 0.206, 0.206 /
                2 - TORSO = CYLINDER / 0.0,0.30,0.353 /
                3 - ABDOMEN = CYLINDER / 0.0,0.30,0.353 /
                 4 - THIGH = CYLINDER / 0.0,0.15,0.383 /
                 5 - CALF = CYLINDER / 0.0, 0.12, 0.328 /
                6 - FOOT = CYLINDER / 0.0, 0.15, 0.104 /
                7 - UPPER ARM = CYLINDER / 0.0,0.096,0.223 /
                8 - LOWER ARM = CYLINDER / 0.0,0.07,0.267 /
                 9 - HAND = SPHERE / -1.0.0.123.0.123 /
        ARRAY COR (9,2) CONTAINS THE CORRESPONDENCE BETWEEN
                 OUR 9 REGION MODEL ID #'S AND THE 12 SEGMENT
                 HODY/ZUMRICK MEASUREMENT SYSTEM ID #'S.
                 THE ROW NUMBERS OF THE ARRAY CORRESPOND TO THE
```

BODY REGION ID'S FOR OUR 9 REGION MAN.
FOR EXAMPLE: 9 REGION MODEL, REGION TORSO(2)
CORRESPONDS TO THE 12 SEGMENT MODEL, SEGMENTS
CHEST(2) AND UPPER BACK (4).

!ROW#	9 REGION MODEL NAME	12 SEGMENT MODEL CORRESPONDING SEGMENTS NAME(ID#) ID #'S ARE IN ARRAY COR(9,2)
! 1	HEAD	HEAD(1),(-1)
!2	TORSO	CHEST(2), UPPER BACK(4)
!3	ABDOMEN	ABDOMEN(3), LOWER BACK(5)
! 4	THIGH	FRONT THIGH(8), REAR THIGH(10)
! 5	CALF	FRONT CALF(9), REAR CALF(11)
! 6	FOOT	FOOT(12),(-1)
!7 .	UPPER ARM	ARM(6),(-1)
! 8	LOWER ARM	ARM(6),(-1)
!9	HAND	WRIST(7),(-1)
į		NOTE (-1) INDICATES THAT ONLY
<u> </u>		ONE CORRESPONDING SEGMENT IS
!		AVAILABLE FROM 12 SEGMENT MODEL

C ARRAY SAM(9) CONTAINS THE REGIONAL SURFACE AREAS OF OUR !MODEL MAN IN METERS SQUARED (M**2)

DATA B/-1. 0, 0. 0, 0. 0, 0. 0, 0. 0, 0. 0, 0. 0, -1. 0

1, 0. 206, 0. 30, 0. 30, 0. 15, 0. 12, 0. 15, 0. 096, 0. 07, 0. 123

2, 0. 206, 0. 353, 0. 353, 0. 383, 0. 328, 0. 104, 0. 223, 0. 267, 0. 123/

3, COR/1, 2, 3, 8, 9, 12, 6, 6, 7, -1, 4, 5, 10, 11, -1, -1, -1, -1/

4, SAM/0. 1333, 0. 3327, 0. 3327, 0. 3610, 0. 2474, 0. 1334

5, 0. 1490, 0. 1174, 0. 0950/

ARRAY KA CONTAINS CONSTANTS, A(i)'S, NEEDED FOR THE !SEGMENTAL TEMPERATURE PREDICTIONS EQUATIONS. THESE !CONSTANTS WERE DERIVED FROM KERSLAKE'S MODEL. SEE !TEXT FOR DETAILS.

VARIABLE KR IS CONTANT R NEEDED FOR SEGMENTAL !TEMPERATURE PREDICTIONS. !THE KR CONSTANT WAS DERIVED FROM A KERSLAKE TYPE MODEL !SEE TEXT FOR DETAILS OF DERIVATION DATA KA/O. 36, O. 27, O. 30, O. 52, -O. 08, O. 22, -O. 64, -O. 04, 1-O. 16, -O. 06, -O. 55, -O. 86/1, KR/2. 946/

C ARRAY GALL (9) CONTAINS THE REGIONAL ALLOWABLE HEAT !FLUXES(W/M**2) ADAPTED FROM THE DATA OF BURRISS, !PRINCIPLE INVESTIGATOR, 'STUDY OF THE THERMAL PROCESSES !FOR MAN IN SPACE', NASA CONTRACT REPORT CR-216.

C ARRAY BF(9) CONTAINS THE REGIONAL BIASING FACTORS USED !TO MAKE PREDICTED OVERALL HEAT TRANSFER COEFFICIENTS

C

```
!AGREE MORE FAVORABLY WITH THE EXPERIMENTAL VALUES.
                 PRED OHTC * BF(i) = CORRECTED PRED OHTC
        DATA GALL/23. 3, 60. 0, 49. 7, 42. 4, 85. 0, 97. 0, 98. 9, 125. 25
        1, 265. 86/
        2, BF/2, 63, 2, 63, 2, 27, 3, 50, 3, 21, 12, 70, 2, 29, 2, 19, 3, 49/
 DEFINITION OF SUIT THERMAL PROPERTIES AND DIMENSIONS
        ! WUGO
                 = WIDTH (THICKNESS) OF UNDER GARMENT AT SEA
                   LEVEL (CM). .
        ! SRO
                 = SPECIFIC RESISTANCE OF UNDER GARMENT
                   AT SEA LEVEL (CLO/CM)
        ! DR
                 = DECIMAL % CHANGE IN SRO PER DECIMAL % CHANGE
                   IN UNDERGARMENT THICKNESS
                   (CLO/CM/CLO/CM/CM/CM) (IE: DIMENSIONLESS)
                   EXPERIMENTALLY DETERMINED.
                                                 SEE TEXT FOR
                   DETAILS.
        ! WOG
                 = WIDTH OF OUTER GARMENT (CM) => 1/16 INCH
        ! CDG
                 = THERMAL CONDUCTIVITY OF OUTER GARMENT MATERIAL
                   WATTS/M*C)
C
                 = ARRAY CONTAINING THE # OF THICKNESSES OF
        TWUGO
                   UNDERGARMENT MATERIAL FOR EACH REGION.
                   EACH LAYER IS 'WUGO' THICK.
        WGT - CONTAINS SURFACE AREA WEIGHTS FOR THE 12 SEGMENT
                 HODY MODEL.
        DATA WUGO, SRO, DR, WOG, COG/1. 63, 2, 27, 0, 1175, 0, 15875
        1, 0, 17307/
        2, TWUGO/1. 0, 1. 0, 1. 0, 1. 0, 1. 0, 2. 0, 1. 0, 1. 0, 1. 0/
        3, WGT/0. 070, 0. 085, 0. 085, 0. 090, 0. 090, 0. 140, 0. 050, 0. 095
        4, 0. 065, 0. 095, 0. 065, 0. 070/
        BREG - ARRAY CONTAIN BODY REGION NAMES FOR PRINT
                 ORDERED ACCORDING TO REGION ID #
        DATA BREG/'HEAD', 'TORSO', 'ABDOMEN', 'THIGH', 'CALF',
        1'FOOT', 'UP ARM', 'LOW ARM', 'HAND', 'TIME'/
           *************************
         !PLOTTING AND COMPARISON VARIABLES
         !SCALY = ARRAY CONTAINS Y AXIS SCALES FOR T, Q, AND U
                   PLOTS
         ! CONTENTS OF ARRAY SCALY(3,3)
         !COLUMN/! 1
                           2
         ! ROW
         ! 1
                 15.0
                         20.0
                                  4.0
                                           TEMPERATURES
         !2
                 15.0
                          0.0
                                  50.0
                                           HEAT FLUXES
         ! 3
                 ! 4. 0
                          0.0
                                  4. 0
                                           TRANSFER COEF.
```

```
!COLUMN 1 CONTAINS LENGTH OF Y-AXIS
!COLUMN 2 CONTAINS STARTING Y-AXIS VALUE
!COLUMN 3 CONTAINS Y-AXIS INCREMENT
       (IE: Y-AXIS UNITS/INCH(CM) )
!SCALYN = ARRAY CONTAINS Y AXIS SCALES FOR
         NORMALIZED TEMPERATURE AND BIOT # PLOTS
! CONTENTS OF ARRAY SCALYN(2,3)
/ ------ / --------
!COLUMN/! 1
! ROW
! 1
        ! 4. 0
                        0. 25
                0. 5
                                NORMALIZED TEMPERATURES
!2
        ! 4. 0
                0.0
                        10.0
                                BIOT NUMBERS
!COLUMN 1 CONTAINS LENGTH OF Y-AXIS
!COLUMN 2 CONTAINS STARTING Y-AXIS VALUE
!COLUMN 3 CONTAINS Y-AXIS INCREMENT
       (IE: Y-AXIS UNITS/INCH(CM) )
!LX
       = LENGTH OF X-AXIS
!SX
       = STARTING VALUE FOR X-AXIS
! IX
        = INCREMENT FOR X-AXIS
!LY
       = LENGTH OF Y-AXIS
!SY
       = STARTING VALUE FOR Y-AXIS
!IY
       = INCREMENT FOR Y-AXIS
!LYS
       = LENGTH Y-AXIS SAVED
! XP
        = ARRAY FOR X-AXIS VALUES FOR PLOTTING
! YP
        = ARRAY FOR Y-AXIS VALUES FOR PLOTTING
!LABEL = ARRAY FOR LEGEND NAMES FOR PLOTS
        = ARRAY FOR SAVING X AND Y VALUES FOR PLOTTING
! P
!FILE
       = ARRAY FOR NAME OF FILE CONTAINING EXPERIMENTAL
          DATA FOR COMPARISON
! TAR
       = TOTAL AREA OF EXPERIMENTAL SUBJECT
! QEXPT
       = SUM OF EXPERIMENTAL Q'S FOR SIMPLE SUM
!UEXPT
       # SUM OF EXPERIMENTAL U'S
!TEXPT = SUM OF EXPERIMENTAL T'S
!PLD
        = INDICATES WHETHER DIMENSIONAL PLOTS
          ARE WANTED OR NOT
! PLN
        = INDICATES WHETHER NON-DIMENSIONAL PLOTS
          ARE WANTED OR NOT
! IR
        = 0,4,6. O= NO LINEARIZED EXPT. PLOTS
                 4= PLOT LINEARIZED EXPT. Q'S
                 6= PLOT LINEARIZED EXPT. U'S
        = SUM OF HODY WEIGHTS FOR CONVERSION
SWGT
          FROM HODY'S 12 SEGMENTS TO THE MODEL'S 9
          REGION FORM.
SWCTT
        = SUM OF HODY WEIGHTS FOR CONVERSION
          OF SEGMENTAL EXPERIMENTAL TEMPERATURES
          FROM HODY'S 12 SEGMENTS TO THE MODEL'S 9
          REGION FORM.
! SWCTQ
        = SUM OF HODY WEIGHTS FOR CONVERSION
          OF SEGMENTAL EXPERIMENTAL HEAT FLOWS
          FROM HODY'S 12 SEGMENTS TO THE MODEL'S 9
          REGION FORM.
```

!SWGTU = SUM OF HODY WEIGHTS FOR CONVERSION OF SEGMENTAL EXPERIMENTAL OVERALL HEAT TRANSFER COEFFICIENTS FROM HODY'S 12 SEGMENTS TO THE MODEL'S 9 REGION FORM. = LENGTH OF EXPT. FILE NAME. (NO. OF CHARACTERS) !LFN = TIME START FOR LINEARIZATION !TS = TIME END FOR LINEARIZATION ! TE = NUMBER OF EXPT. RECORDS (TIMES) AVAILABLE FOR ! NREC COMPARISON = Y OR N, INDICATES DESIRE FOR COMPARISON OF ! QCOMP EXPERIMENTAL VALUE WITH PREDICTIONS. !EXP IS THE ARRAY USED TO READ IN EXPERIMENTAL DATA !VALUES FOR COMPARISON !ARRAY G CONTAINS THE 9 COMPUTED REGIONAL HEAT FLUXES !ARRAY QP CONTAINS THE 9 COMPUTED REGIONAL HEAT FLOWS !ARRAY QA CONTAINS THE 9 ASSUMED REGIONAL ALLOWABLE !HEAT FLOWS !ARRAY QSUPP CONTAINS THE 9 COMPUTED REQUIRED !REGIONAL HEAT FLOWS ARRAY SCALY IS ENTERED INTO THE COMPUTER VIA A DATA !STATEMENT IN COLUMN MAJOR ORDER AS: LYT, LYQ, LYU, SYT, SYQ, SYU, IYT, IYQ, IYU WHERE: LYX => LENGTH OF Y-AXIS SYX => STARTING VALUE FOR Y-AXIS IYX => INCREMENTING VALUE FOR Y-AXIS (X IN THE ABOVE IMPLIES T'S, G'S, OR U'S) ARRAY SCALN IS ENTERED INTO THE COMPUTER VIA A DATA STATEMENT IN COLUMN MAJOR ORDER AS: LYTN, LYBI, SYTN, SYBI, IYTN, IYBN WHERE: LYXX => LENGTH OF Y-AXIS SYXX => STARTING VALUE FOR Y-AXIS IYXX => INCREMENTING VALUE FOR Y-AXIS (XX IN THE ABOVE IMPLIES TN'S OR BI'S) VARIABLES LX, SX, IX ARE ENTERED INTO THE PROGRAM VIA !A DATA STATEMENT AS: ! LX,SX,IX WHERE: LX => LENGTH OF X-AXIS SX => STARTING VALUE FOR X-AXIS IX => INCREMENTING VALUE FOR X-AXIS SYM IS A VECTOR CONTAINING THE INTEGERS CORRESPONDING ITO THE SYMBOLS TO BE USED FOR THE EXPERIMENTAL AND !PREDICTED VALUES RESPECTIVILY. DATA SCALY/5. 0, 5. 0, 4. 0, 20. 0, 0. 0, 0. 0, 4. 0, 50. 0, 4. 0/

```
1, SCALYN/4, 0, 4, 0, 0, 5, 0, 0, 0, 25, 10, 0/
       2, LX, SX, IX/7. 0, 0. 0, 20. 0/
        3,5YM/3,4/
C***************
        THE FOLLOWING VARIABLES ARE USED AS TEMPORARY VARIABLES
        ! AND HAVE NO PERMANENT MEANING
        !DUM, I, J, L, M, N
C***************
        !THIS SYSTEM LEVEL SUBROUTINE CALL IS USED TO ATTACH THE
        !TERMINAL TO THIS TASK.
                                THIS PREVENTS RETURNS USED TO
        !TERMINATE RESPONSES FROM BEING INTERPRETED BY THE
        !OPERATING SYSTEMS MONITOR CONTROL ROUTINE.
        CALL WTGIO ("1420,"5)
C MAIN
                VARIABLES DEFINED IN MODULE MAIN
        !FLAG2
               = DEBUG PRINT FLAG (-1=>YES, 0=>NO)
        BR
               = BODY REGION ID (0-9)
        !RD
                = REFERENCE DEPTH => DEPTH BELOW SEA LEVEL
                 OF SHOULDER LINE (FSW, MSW, PSI)
        ! RDU
                = INDICATOR OF UNITS OF
                  (F=FSW, M=MSW, P=PSI)
        ! NN
                = # OF NODE TO DEVIDE EACH REGION INTO
                 FOR FINITE DIFFERENCE CALCULATIONS
        ! DUT
                = VARIABLE CONTAINING DESIRED LOCATION
                 FOR OUTPUT PRINTS (T=TERMINAL,
                  F=DR: DMPDAT. LST)
                = TEMPERATURE - MEAN SKIN - AT WHICH TO PERFORM
        ! TDMS
                  CALCULATIONS (DESIGN MEAN SKIN TEMPERATURE)
        !TA
                = TEMPERATURE - AMBIENT - AT WHICH TO PERFORM
                  CALCULATIONS
        ! T1
                = TEMPERATURE OF THE SKIN SURFACE
        !ATT
                = ATTITUDE OF SUBJECT (DIVER)
                  (O=SITTING, 1=STANDING, 2=LAY HORTIZONTAL)
                = FLAG VARIABLE INDICATING WHETHER OR NOT
        ! ITOT
                  DOING ALL REGIONS OR A SINGLE REGION
                  ( -1=>ALL REGIONS, O=>SINGLE REGION)
                = VARIABLE CONTAINING LOGICAL UNIT #
        ! LO
                  AT WHICH TO PRINT DUTPUT PRINTS
                  (5=>TERMINAL, 3=>DR: DMPDAT. LST)
        ! U
                = VARIABLE CONTAINING RESULTS OF CALCULATION
                  OF OVERALL HEAT TRANSFER COEFFICIENT
                  FOR SPECIFIED NODE OF SELECTED REGION
        ! US
                = VARIABLE CONTAINING RUNNING SUM OF NODAL
                  U'S
        ! UN
                = VARIABLE CONTAINING THE COUNT OF THE
                  NUMBER OF NODES IN THE SUM (US)
        ! QR
                = VARIABLE CONTAINING HEAT LOSS CALCULATED FOR
                  EACH NODE
                = REQUIRED SUPPLEMENTARY HEAT FLUX FOR
        ! QSUP
                  THE REGION OF INTEREST
        !THE FOLLOWING VARIABLE FOUND IN MODULE MAIN ARE
```

```
!DEFINED IN OTHER MODULES (SUBROUTINES, FUNCTIONS)
        !DZ, DZV, FLAG1, ROBL, ROG, RUG, RUGHA, R1, R2, R3, T3
        !INTEGER VARIABLE 'IB' AND ARRAY 'PRTL' ARE BOTH USED
        !BY THE OUTPUT PRINTING ROUTINES.
        !THESE VARIABLES HAVE BEEN ASSIGNED TO ALLOW MORE
        !EFFICIENT USE OF THE FORTRAN CODE
        DATA PRTL/' ', 'C', 'O', 'R', 'R', 'E', 'C', 'T', 'E', 'D', ' '/
        1, IB/'--'/
30
        WRITE (5,31)
        FORMAT ('$ARE YOU A RESEARCH USER ? (Y, N, X) ')
31
C
        THESE VARIABLE ARE BEING PRE-DEFINED FOR THE
        PRODUCTION MODE. ALL OF THESE VARIABLE CAN BE
        DYNAMICALLY MODIFIED IN THE RESEARCH MODE.
        REU= 'N'
        BR=0
        FLAG2=0
        FLAC1=0
        IR=0
        NN=1
        OUT='T'
        GCOMP='N'
        READ (5,32) REU
32
        FORMAT (1A1)
        IF (REU. NE. 'Y'. AND. REU. NE. 'N'. AND. REU. NE. 'X')
        1 QO TO 30
        IF (REU. EQ. 'N') GO TO 44
        IF (REU. EQ. 'X') GO TO 15
        WRITE (5,39)
        FORMAT ('$DO YOU WISH TO CORRECT PREDICTED '
39
        1, '''U'' VALUES ? (Y/N) ')
        READ (5,32) DUM
        IF (DUM. EQ. 'Y') REU='S'
40
        WRITE (5,41)
41
        FORMAT ('$DO YOU WISH DEBUG PRINTS: ? (Y/N):
        READ (5,32) DUM
        FLAG2=-1
        IF (DUM. EQ. 'Y') GO TO 44
        FLAG2=0
        WRITE (5,6)
44
        FORMAT ('$ENTER DEPTH IN (M)SW, (F)SW OR (P)SIG BY '
         1, '(M#,F#,P#): [F]', T70)
        READ (5,7) RDU, RD
        FORMAT (1A1, F10, 2)
71
        WRITE (5,72)
        FORMAT (' SELECT BREATHING GAS: ',/
72
         1, '$(A) IR OR OXYGEN MIXED WITH (H) ELIUM OR (N) ITROGEN'
         2, ' (A, H, N):
                        ', T70)
         READ (5,32) IQ
         IF (IG. EQ. 'A') QO TO 50
         WRITE (5,73) IG
73
         FORMAT ('$ ENTER MOLE FRACTION OF INERT ', 1A1
```

```
1, ' COMPONENT:
                          [F] ', T70)
        READ (5,74) YG
74
        FORMAT (F6.3)
50
        WRITE (5,51) (IB, M=1,39), SRO, WUGO, WDG, CDG
51
        FORMAT (' ', 39A2, /, ' SEA LEVEL GARMENT ENSEMBLE '
        1, 'PROPERTIES', /
        2, '01-SPECFIC THERMAL RESISTANCE OF UNDERGARMENT:
        3, '(CLD/CM)'
        4, T58, F8. 2, /, ' 2-UNIT THICKNESS OF UNDERGARMENT: '
        5, '(CM)'
        6, T58, F8. 2, /, ' 3-THICKNESS OF OUTER '
        7, 'GARMENT: (CM)', T58, F8. 4, /, ' 4-THERMAL CONDUCTIVITY'
        8, ' OF OUTER GARMENT: (W/M*C) '
        9, T58, F8. 4, /, '$ENTER (1-4) TO ALTER, (R) '
        1, 'TO REINITIALIZE, (X) FOR NO '
        2, 'CHANGE:
                     13
        READ (5,32) IT
        IF (IT. EQ. 'X') GO TO 58
        IF (IT. EQ. 'R') FL4=REINIT(1)
        IF (IT. EQ. 'R') GO TO 50
        DECODE (1,53,IT) IT
53
        FORMAT (11)
        GO TO (54,55,56,57) IT
        GO TO 50
54
        WRITE (5,541)
        FORMAT ('$ ENTER 1 - SPECIFIC THERMAL RESISTANCE '
541
        1, 'OF UNDERGARMENT (CLO/CM): [F]
        READ (5,542) SRO
542
        FORMAT (F10.2)
        GD TD 50
        WRITE (5,551)
55
551
        FORMAT ( '$ ENTER 2 - UNIT THICKNESS OF UNDERGARMENT'
        1, ' (CM): [F] ')
        READ (5,552) WUGO
552
        FORMAT (F10.3)
        GD TD 50
56
        WRITE (5,561)
        FORMAT ('$ ENTER THICKNESS OF OUTER GARMENT (CM): [F] ')
561
        READ (5,562) WOG
562
        FORMAT (F10.5)
        GO TO 50
57
        WRITE (5,571)
571
        FORMAT ('$ ENTER THERMAL CONDUCTIVITY OF OUTER GARMENT '
        1, ' (W/M+C): [F] ')
        READ (5,572) CDG
572
        FORMAT (F10.5)
        QD TD 50
58
        WRITE (5,580) (IB, M=1,39), (M, BREG(M), TWUGO(M), WUGO
         1, (TWUGO(M) + WUGO), M=1, 9)
580
        FORMAT (' ', 39A2, /, ' REGIONAL UNDERGARMENT THICKNESS'
        1, ' (CM) ', /, 'O', T37, 'UNIT', T47, 'ACTUAL', /
        2, ' ', T4, 'ID #', T12, 'REGION', T23, 'MULTIPLIER', T35
        3, 'THICKNESS', T46, 'THICKNESS', /
```

```
4.9(5X, 11, 5X, 1AB, 5X, F6, 2, ' * ', F6, 2, ' = ', FB, 4, /), /
        5, '$ENTER (1-9) TO ALTER, (R) TO '
        6, 'REINITIALIZE, (X) FOR NO CHANGE:
        READ (5,32) IT
        IF (IT. EQ. 'X') GO TO 59
        IF (IT. EQ. 'R') FL4=REINIT(2)
        IF (IT. EQ. 'R') GO TO 58
        DECODE (1,53,IT) IT
        WRITE (5,584) IT, BREG(IT)
584
        FORMAT ('SENTER NEW MULTIPLIER FOR ', I1, '-', 1A8
        1, ': [F] ')
        READ (5,585) TWUGO(IT)
585
        FORMAT (F6. 2)
        GO TO 58
59
        WRITE (5,590) (IB, M=1,39), (M, BREG(M), GALL(M), M=1,9)
590
        FORMAT (' ', 39A2, /, ' ALLOWABLE REGIONAL HEAT FLUX'
        1, ' (W/M**2)', /, 'O', T32, 'ALLOWABLE', /, ' ', T4, 'ID #'
        2, T12, 'REGION', T32, 'HEAT FLUX', /
        3,9(' ',5X, I1,5X, 1A8, 10X, F10. 2, /),/
        4, '$ENTER (1-9) TO ALTER, (R) TO '
        1, 'REINITIALIZE, (X) FOR NO CHANGE:
        READ (5,32) IT
        IF (IT. EQ. 'X') GO TO 60
        IF (IT. EQ. 'R') FL4=REINIT(3)
        IF (IT. EQ. 'R') GD TD 59
        DECODE (1,53,IT) IT
        WRITE (5,591) IT
591
        FORMAT ('SENTER ALLOWABLE HEAT FLUX FOR REGION '
        1, I1, ' (W/M**2): [F] ')
        READ (5,592) GALL(IT)
592
        FORMAT (F10.3)
        GO TO 59
60
        WRITE (5,600) (IB, M=1,39), (M, BREG(M), BF(M), M=1,9)
600
        FORMAT (' ', 39A2//, ' REGIONAL BIASING FACTORS'
        1, ' (DIMENSIONLESS)',/
        2, '0', T4, 'ID #'
        3, T12, 'REGION', T31, 'BIASING FACTOR', /
        4,9(' ',5X, I1,5X, 1A8, 10X, F10, 2,/),/
        5, '$ENTER (1-9) TO ALTER, (R) TO '
        6, 'REINITIALIZE, (X) FOR NO CHANGE:
        READ (5,32) IT
        IF (IT. EQ. 'X') GO TO 609
         IF (IT. EQ. 'R') FL4=REINIT(4)
        IF (IT. EQ. 'R') GD TO 60
        DECODE (1,53,IT) IT
        WRITE (5,601) IT
        FORMAT ('SENTER BIASING FACTOR FOR REGION'
601
         1, I1, ' (DIMENSIONLESS): [F] ')
        READ (5,602) BF(IT)
602
        FORMAT (F10.3)
        GO TO 60
609
        WRITE (5,111)
111
        FORMAT ( 'SWRITE OUTPUT FILE WHERE: '
```

```
1, '(T=SCREEN, F=DMPDAT, LST)
        READ (5,32) OUT
        WRITE (5,10)
        FORMAT ('$ENTER # NODES: [1] ')
10
        READ (5,11) NN
11
        FORMAT (114)
        IF (REU. EQ. 'N') GO TO 43
        WRITE (5,16)
        FORMAT ('$DO YOU WISH TO COMPARE T.G.U VALUES WITH '
16
        1, 'EXP''T DATA: (Y/N)
                                1)
        READ (5,161) GCOMP, CH
        FORMAT (1A1,: F10.2)
161
        IF (QCDMP, NE. 'Y') GO TO 43
        NREC=0
162
        WRITE (5, 1621)
        FORMAT ('SENTER TOTAL SURFACE AREA OF EXP''T'
1621
        1' SUBJECT IN M**2: [F] ')
        READ (5,1622) TAR
1622
        FORMAT (F10.2)
        IF (TAR. LE. O. O) GO TO 162
        WRITE (5,1630)
163
        FORMAT ('SENTER EXPERIMENTAL DATA FILE NAME:
                                                          1)
1630
        READ (5,1631) LFN, (FILE(L), L=1, LFN)
1631
        FORMAT (G, <LFN>A1)
        FILE(LFN+1)="0
                                  !WRITE NULL
        OPEN (UNIT=2, TYPE='OLD', ACCESS='DIRECT',
        1NAME=FILE, FORM='FORMATTED',
        2CARRIAGECONTROL='FORTRAN', READONLY,
        3RECORDSIZE=200, ERR=163)
        READ (2'1, 164) NREC
164
        FORMAT (14)
        GD TO 114
43
        WRITE (5,431) (IB, M=1,39)
        FORMAT (' ',39A2,/,'$ENTER DESIGN MEAN SKIN'
431
        1, 'TEMPERATURE (C): [F]', T65)
        READ (5,433) TDMS
433
        FORMAT (F10.3)
        WRITE (5,432)
4330
        FORMAT ('$ENTER AMBIENT TEMPERATURE >= 1.0 C: [F]', T65)
432
        READ (5,433) TA
        IF (TA.LT. 1.0) QO TO 4330
        WRITE (5,8)
114
        FORMAT ('$SELECT BODY REGION (1-9) OR (0) FOR ALL '
8
         1, 'REGIONS: [1]', T65)
        READ (5,81) BR
        FORMAT (I10)
81
        WRITE (5,82)
        FORMAT ('$SELECT POSTURE OF SUBJECT (0-SIT, 1-STAND, '
82
         1, '2-PRONE): [I]', T65)
        READ (5,81) ATT
         ITOT=0
         IF (BR. EQ. 0) ITOT=-1
        PRT(1)=' '
```

```
PV=2
        IF (REU. EQ. 'S'. OR. REU. EQ. 'N') GO TO 821
        PRT(2)='U'
        PRT(3)='N'
        PV=4
821
        DO 822 M=2,11
        PRT(PV)=PRTL(M)
822
        PV=PV+1
        PV=PV-1
        IF (ITOT. EQ. 0) GO TO 113
        DO 14 BR=1,9
113
        L0=5
        IF (OUT. EQ. 'T') GO TO 1130
        L0=3
        OPEN (UNIT=LO, NAME='SY: DMPD高了, LST')
1130
        WRITE (LD, 11301)
11301
        FORMAT ('0')
        IF (QCOMP. NE. 'Y') GO TG 1134
        DO 150 I=1, NREC
        READ (2'I+1,1131) EXP
1131
        FORMAT (13F8, 2, 15F6, 2, 产益, 1)
         TA=EXP(27)
        IF (TA. GT. O. O) GD TD 11311
        DO 11310 J=2,7
        P(I,J)=-1.0
11310
        CONTINUE
11311
        TDMS=0. 0
        SWGT=0. 0
        DO 1132 M=14,25
C
 DROP VALUE & WEIGHT FROM SUM IF 'T' VALUE <= 0.0
         IF (EXP(M). LE. 0. 0) GO TO 1132
         TDMS=TDMS+(WGT(M-13)*EXP(M))
        SWGT=SWGT+WGT(M-13)
1132
        CONTINUE
         IF (SWGT. EQ. O. O) GO TO 11321
        TDMS=TDMS/SWGT
11321
        P(I,1)=EXP(1)
        WRITE (LD, 1133) EXP(1)
1133
        FORMAT (' EXPERIMENTAL TIME: ', F8. 2)
1134
        LY= ' MSW '
         IF (RDU. EQ. 'F') LY=' FSW'
         IF (RDU.EQ. 'P') LY= ' PSI'
         T1=TR(TDMS,BR)
         WRITE (LO, 115) BR, ATT, TDMS, RD, LY, TA, BR, T1
115
        FORMAT ('OBODY REGION: ', T56, I10, /
         1, ' POSTURE: O=SIT, 1=STAND, 2=PRONE', T56, I10, /
         2, ' DESIGN MEAN SKIN TEMPERATURE: ', T54, F10. 2, ' C', /
         3, ' REFERENCE DEPTH: ', T52, F10. 2, 1A4, /
         4, ' AMBIENT TEMPERATURE: ', T54, F10. 2, ' C', //
         5, PREDICTED TEMPERATURE FOR REGION ', I1, ': ', T54
         6, F10. 2, ' C')
         IF (NN. EQ. 1) GO TO 116
         WRITE (LO, 1151) NN
```

```
FORMAT (' NUMBER OF NODES: ', T56, I10)
1151
116
        G(BR)=0.0
        US=0. 0
        UN=0. 0
        ! NOTE:
                HEAD(1) AND HAND(9) ARE SPHERES AND ARE THUS
                MODELED AS HAVING ONE NODE ONLY FOR ALL
                 ATTITUDES, 0=SIT, 1=STAND, 2=LAY HORT.
                 THIGH(4) IS A HORTIZONTAL CYLINDER FOR
                 ATT = O(SIT) AND THUS HAS ONLY ONE NODE
                 WHEN ATT=1(STAND), 2(LAY HORT) THIGH(4)
                MATCHS ALL THE OTHER CYLINDERS IN
                 ATTITUDE
        IF (BR. NE. 1. AND. BR. NE. 9. AND. (BR. NE. 4. OR. ATT. NE. 0))
        1 GO TO 1161
        J=1
        GO TO 118
        ! NOTE:
                P(I,1)=TIME
                 P(I,2)=T EXPERIMENTAL
                 P(I,3)=T PREDICTED
                P(I, 4)=Q EXPERIMENTAL
                P(I,5)=@ PREDICTED
                P(I,6)=U EXPERIMENTAL
                P(I,7)=U PREDICTED
                P(I,8)=TDMS
                P(I,9)=TA
1161
        DO 13 J=1, NN
        IF (NN. EQ. 1) GO TO 118
        IF (J. EG. 1) WRITE (LO, 11611)
11611
        FORMAT ('O')
        WRITE (LO, 1162) BR, J
1162
        FORMAT (' REGION ', I1, ' NODE ', I4)
        U=OHTC(J)
118
        !CHECK TO SEE IF CONVECTIVE HEAT TRANSFER COEFFICIENT
        ! WAS SUCCESSFULLY DETERMINED. FLAG3=0.0 => SUCCESS
        ! FLAG3=1.0 AND FLAG3=2.0 => FAILURE (SEE SUBROUTINE
         ! CHTC FOR DIFFERENCE BETWEEN FLAG3=1.0 AND 2.0)
        IF (FLAG3. GT. O. O) GO TO 148
        !CHECK TO SEE IF OHTC WAS SUCCESSFULLY DETERMINED.
         ! FLAG1 >= -1 SUCCESS, FLAG1 < -1 FAILURE.
        ! (SEE SUBROUTINE OHTC FOR MEANING OF VARIOUS
         ! VALUES OF FLAG1)
        IF (FLAG1. GE. -1) GO TO 1181
        IF (FLAG1. NE. -3) QO TO 11801
        WRITE (LO, 1180) T3, TA
1180
        FORMAT (' ESTIMATE OF OUTSIDE SURF. TEMP., ', F5. 2
        1, 'LESS THAN AMBIENT TEMP., ',F5.2)
        GO TO 11803
11801
        WRITE (LO, 11802) NTOL
11802
        FORMAT ( ' MAXIMUN # OF ITERATIONS (NTOL= '
        1, 14, ') ALLOWED FOR ESTIMATING', /
```

```
2, ' THE OUTSIDE SURFACE TEMPERATURE OF THE '
        3, 'ENSEMBLE BY THE SECANT METHOD EXCEEDED')
11803
        WRITE (LQ, 11804)
11804
        FORMAT (20%, ' RUN TERMINATED !')
        GO TO 148
        IF DOING PRODUCTION MODE RUN (REU=N) THEN MUST APPLY
         BIASING FACTOR BF(BR) TO THE NODAL U VALUE .
         !NOTE: ONLY ON NODE IS DEFINED PER REGION IN THE
         !PRODUCTION MODE.
1181
        IF (REU. EQ. 'N'. DR. REU. EQ. 'S') U=U+BF(BR)
        US=US+U
        UN=UN+1. 0
        QR=U*(T1-TA)
                                   !WATT/M2
        G(BR)=G(BR)+(GR*SAM(BR)/FLDAT(NN)) !WATTS
        IF (FLAG2. EQ. 0) QD TD 119
        WRITE (LO, 1182) RUG, ROG, ROBL, R1, R2, R3, T1, T3
        1, FLAG1, F(T3), CHTC(T3, R3), US, UN, QR, Q(BR)
1182
        FORMAT (' RUG, RDG, RDBL', 1P, 3G15, 7, /
        1, ' R1, R2, R3', 3Q15, 7, /
        2, ′
              T1, T3', 2G15, 7, OP, /
        3, '
              FLAG1, F(T3), CHTC(T3, R3) ', I7, 1P, 2G15, 7, /
        4, '
              US, UN', 2G15.7,/
         5, '
              QR, Q(BR) ', 2Q15.7)
C
        Q(BR)=Q(BR)+(QR*SAM(BR)/FLOAT(NN)) !WATTS
        NOTE: MULTIPLYING NODAL HEAT FLUX 'QR' BY
C
        REGIONAL SURFACE AREA 'SAM(BR)' DIVIDED BY THE
C
        NUMBER OF NODES 'FLOAT(NN)' FORCES THE EXTRA AREA
C
        CONTRIBUTED BY A CYLINDER BOTTOM AND
C
        A CYLINDER TOP, REGIONS 6 AND 7
        RESPECTIVILY, TO BE INCLUDED IN THE
        LATTERAL SURFACE AREA.
                                   THIS IS
        CONSISTANT WITH THE AREA ASSUMED
        FOR HEAT LOSS IN THE DEVELOPMENT
        OF THE OHTC.
119
         IF (NN. EQ. 1) GO TO 126
        WRITE (LO, 125) (PRT(L), L=1, PV), J, U, J, QR
125
        FORMAT (<PV>A1, 'PREDICTED OHTC FOR NODE '
         1, I4, ': ', T47, F10, 2, ' W/M**2*C', /
         2, ' PREDICTED HEAT FLUX FOR NODE
         3, 14, ': ', T49, F10, 2, ' W/M**2', //)
126
         IF (BR. EQ. 1. OR. BR. EQ. 9. OR. (BR. EQ. 4. AND. ATT. EQ. 0))
         1 00 TO 142
13
         CONTINUE
142
         Q(BR)=Q(BR)/SAM(BR)
                                   !W/M**2
         U=US/UN
         WRITE (LD, 144) (PRT(L), L=1, PV), BR, U, BR, Q(BR), BR, QALL(BR)
        FORMAT (<PV>A1, 'PREDICTED OHTC FOR REGION ', I1, ': ', T47
144
         1,F10.2,' W/M**2*C',/
         2, ' PREDICTED UNIT HEAT FLUX FOR REGION ', I1
         3, ': ', T49, F10. 2, ' W/M**2', /, ' ALLOWABLE UNIT HEAT FLUX '
         4, 'FOR REGION ', I1, ': ', T49, F10. 2, ' W/M**2')
```

```
QA(BR)=GALL(BR)*SAM(BR)
        QP(BR)=Q(BR)*SAM(BR)
        QSUPP(BR)=QP(BR)-QA(BR)
        QSUP=Q(BR)-GALL(BR)
        WRITE (LO, 131) QSUP, BR, QP(BR), BR, QA(BR), QSUPP(BR)
131
        FORMAT (' REQUIRED SUPPLEMENTARY HEAT FLUX: ', T49, F10. 2
        1, ' W/M**2', /
        2, ' PREDICTED RATE OF HEAT LOSS FOR REGION ', I1, ': '
        3, T50, F10, 2, 'WATTS', /, 'ALLOWABLE RATE OF HEAT LOSS '
        4, 'FOR REGION ', I1, ': ', T50, F10, 2, ' WATTS', /
        5, ' REQUIRED SUPPLEMENTARY HEATING: ', T50, F10, 2
        6, ' WATTS')
        IF (QCDMP, NE. 'Y') QO TO 148
        P(I,3)=T1
        P(I,5)=Q(BR)
                                   !WATTS/M2
                                   !WATTS/M2*C
        P(I,7)=US/UN
        P(I,8)=TDMS
                                   !T DES. MEAN SKIN
                                   !T AMBIENT
        P(I,9)=TA
        TEXPT=0. 0
        UEXPT=0. 0
        QEXPT=0. 0
        SWGTT=0. 0
        SWGTQ=0. 0
        SWCTU=0. 0
        DO 1437 L=1,2
        M=COR(BR,L)
        IF (M. EQ. -1) GO TO 1437
   DROP VALUE & WEIGHT FROM SUM IF 'T' VALUE <= 0.0
        IF (EXP(M+13). LE. 0. 0) QO TO 1435
        TEXPT=TEXPT+(WGT(M)*EXP(M+13))
        SWGTT=SWGTT+WGT(M)
C DROP VALUE & WEIGHT FROM SUM IF 'Q' VALUE <= 0.0
        IF (EXP(M+1). LE. O. O) GO TO 1436
1435
        QEXPT=GEXPT+EXP(M+1)
                                   ! WATTS
        SWGTQ=SWGTQ+WGT(M)
C DROP VALUE & WEIGHT FROM SUM IF 'G' VALUE <= 0.0
1436
         IF (EXP(M+1), LE. O. O. OR, EXP(M+13), LE. O. O) GO TO 1437
        UEXPT=UEXPT+(EXP(M+1)/(EXP(M+13)-TA))
         SWCTU=SWCTU+WCT(M)
1437
         CONTINUE
         IF (SWGTT. EQ. 0. 0) 90 TO 1438
         TEXPT=TEXPT/SWGTT
1438
         IF (SWGTG. LE. O. O) QD TD 1439
         GEXPT=GEXPT/(TAR*SWGTG) !W/M2
         IF (SWGTU. EQ. 0. 0) QO TO 1440
1439
         UEXPT=UEXPT/(SWGTU*TAR)
1440
         P(I,2)=TEXPT
         P(I,4)=QEXPT
         P(I,6)=UEXPT
         M=2
         PU(1)=', '
         PU(2)=';'
         IF (COR(BR, 2), EQ. -1) M=1
```

```
IF (M. EQ. 1) PU(1)=';'
        WRITE (LO, 1441) (COR(BR, L), PU(L), L=1, M), BR, TEXPT
        1, (COR(BR, L), PU(L), L=1, M), BR, UEXPT
        2, (COR(BR, L), PU(L), L=1, M), BR, QEXPT
1441
        FORMAT (' WGT''ED EXP''T TEMP, SITE(S) '
        1, <M>(I2, A1), ' REGION ', I1, ': ', T54
        2,F10.2,' C',/
        3, ' WGT''ED EXP''T OHTC, SITE(S) '
        4, <M>(12, A1), ' REGION ', 11, ': ', T47
        5, F10. 2, ' W/M**2*C', /
        6, ' WGT''ED EXP''T HEAT FLUX, SITE(S) '
        7, <M>(I2, A1), ' REGION ', I1, ': ', T49
        8,F10.2,' W/M**2')
148
        WRITE (LO, 149) (IB, M=1, 32)
149
        FORMAT ( ' ', 32A2)
        IF (QCDMP. NE. 'Y') QD TD 360
150
        CONTINUE
        IF (ITOT. EQ. -1. AND. BR. GT. 1) GO TO 152
        PRT(1)='('
        LCL=2
        IF (REU. EQ. 'S') GO TO 1501
        PRT(2)='U'
        PRT(3)='N'
        LCL=4
1501
        DO 1502 M=2,10
        PRT(LCL)=PRTL(M)
1502
        LCL=LCL+1
        PRT(LCL)=')'
        WRITE (5, 151)
        FORMAT ('$DO YOU WISH TO PLOT T''S, Q''S, AND U''S? '
151
         1, '(Y/N)
                   1)
        READ (5,32) PLD
         IF (PLD. NE. 'Y') GO TO 249
        LABEL(1)='T C'
1510
        LABEL(2)='Q W/M2'
        LABEL(3)='U W/M2*C'
        WRITE (5,1511) (LABEL(M), (SCALY(M, N), N=1,3), M=1,3)
1511
        FORMAT (' ', 10X, 'Y-AXIS SCALE FACTORS', //
         1, 10X, 7X, 'LY', 10X, 7X, 'SY', 10X, 7X, 'IY', /
        2,3(1X,A8,1X,3(F10,2,9X),/),/
         3, '$SELECT: (1=T, 2=G, 3=U, X=NO MORE CHANGES)
                                                          1)
         READ (5,32) IT
         IF (IT. EQ. 'X') GO TO 1517
         DECODE (1,1514, IT) L
1514
         FORMAT (I1)
         IF (L. LE. O. OR. L. GE. 4) GO TO 1517
         WRITE (5,1515) LABEL(L)
1515
         FORMAT ('$ENTER', A8, ' LY, SY, IY SEPARATED BY COMMAS: '
         1' [F] ')
         READ (5,1516) (SCALY(L,M),M=1,3)
         FORMAT (3F10.3)
1516
         GD TD 1510
1517
         WRITE (5,1518) LX,SX,IX
```

```
1518
        FORMAT (' ',10X, 'X-AXIS (TIME) SCALE FACTORS',//
        1, 10X, 7X, 'LX', 10X, 7X, 'SX', 10X, 7X, 'IX', /
        2, (1X, 'T, Q, U MIN', 3(F10. 2, 9X), /), /
        3, '$CHANGE X-AXIS? (Y/N)
        READ (5,32) IT
        IF (IT. NE. 'Y') GO TO 152
        WRITE (5, 1519)
1519
        FORMAT ('$ENTER LX, SX, IX SEPARATED BY COMMAS: [F] ')
        READ (5,1516) LX,SX,IX
        GD TO 1517
152
        IF (PLD. NE. 'Y') GO TO 249
        DO 200 K=1,3
        CALL NEWDEY (, 'DRO: COMPAR. VEC', 14)
        CALL PLOTST (4, 'IN', 1)
        CALL PLOT (1.0, 1.0, -3)
        CALL AXIS (0.0,0.0, 'TIME (MIN)',-10, LX, 0.0, SX, IX)
        GO TO (190,170,180) K
190
        LY=SCALY(K, 1)
        SY=SCALY(K, 2)
        IY=SCALY(K,3)
        LYS=LY
        CALL AXIS (0.0,0.0, 'TEMPERATURE (C)',+15, LY, 90.0, SY, IY)
        LABEL(1)='T-EXPT
        LABEL(2)='T-PRED
        OPEN (UNIT=6, NAME='DR: COMPAR. OUT')
        WRITE (6,191) BREG(BR), LY, SY, IY
        FORMAT ( ' ', 7X, 1AB, /, ' ', 7X, 'LY: ', F7. 2, 5X, 'SY: '
191
        1, F7. 2, 5X, 'IY: '
        2, F7. 2, /, ' ', 7X, '* INDICATES POINT NOT PLOTTED; '
        3, ' ITS VALUE IS <= 0 OR < SY', /
        4,12X, 'TIME ',12X, 'T-EXPT ',10X
                      (,/)
        5, T-PRED
        CALL PLOTD(1, SYM, BR)
        CALL PLOTND
        CLOSE (UNIT=6)
        GD TO 200
170
        LY=SCALY(K, 1)
        SY=SCALY(K, 2)
        IY=SCALY(K, 3)
        LYS=LY
        CALL AXIS (0.0,0.0, 'HEAT FLUX (W/M2) ',+19,LY
        1, 90. 0, SY, IY)
        LABEL(1)='Q-EXPT
        LABEL(2)='Q-PRED
        OPEN (UNIT=6, NAME='DR: COMPAR. OUT')
        WRITE (6,171) BREG(BR), (PRT(M), M=1, LCL), LY, SY, IY
171
        FORMAT (' ',7X,1AB,<LCL>A1,/,' ',7X,'LY:',F7,2,5X,'SY:'
        1, F7. 2, 5X, 'IY: '
        2, F7. 2, /, ' ', 7X, '* INDICATES POINT NOT PLOTTED; '
        3, ' ITS VALUE IS <= 0 OR < SY', /
         4,12X, ' TIME ',12X, ' Q-EXPT ',10X
                      1,/)
         5, ' Q-PRED
        CALL PLOTD (3, SYM, BR)
```

```
CALL PLOTND
        CLOSE (UNIT=6)
        GD TD 200
180
        LY=SCALY(K, 1)
        SY=SCALY(K, 2)
        IY=SCALY(K,3)
        LYS=LY
        CALL AXIS (0.0,0,0,'OHTC (W/M2*C)',+13,LY,90,0,SY,IY)
        ·LABEL(1)='U-EXPT
        LABEL(2)='U-PRED
        OPEN (UNIT=6, NAME='DR: COMPAR. OUT')
        WRITE (6.181) BREG(BR), (PRT(M), M=1, LCL), LY, SY, IY
181
        FORMAT (' ',7X,1AB, <LCL>A1, /, ' ',7X, 'LY: ',F7. 2,5X, 'SY: '
        1, F7. 2, 5X, 'IY: '
        2, F7. 2, /, ' ', 7X, '* INDICATES POINT NOT PLOTTED; '
        3, ' ITS VALUE IS <= 0 DR < SY', /
        4,12X, 'TIME',14X, ' U-EXPT ',10X
        5, ' U-PRED ', /)
        CALL PLOTD (5, SYM, BR)
        CALL PLOTND
        CLOSE (UNIT=6)
200
        CONTINUE
249
        IF (ITOT. EQ. -1. AND. BR. GT. 1) GO TO 320
        WRITE (5,300)
300
        FORMAT ('$DO YOU WISH TO PLOT NORMALIZED T''S AND'
        1, ' BIOT #''S ? (Y/N)
        READ (5,32) PLN
        IF (PLN. NE. 'Y') GO TO 360
310
        LABEL(1)='TN'
        LABEL(2)='BI'
        WRITE (5,311) (LABEL(M), (SCALYN(M, N), N=1,3), M=1,2)
        FORMAT (' ', 10X, 'Y-AXIS SCALE FACTORS', /
311
        1, ' ', 8X, 'NON-DIMENSIONAL T''S & U''S', //
        2,10X,7X,'LY',10X,7X,'SY',10X,7X,'IY',/
        3,2(1X,A8,1X,3(F10,2,9X),/),/
         4, '$SELECT: (1=TN, 2=BI, X=NO MORE CHANGES)
        READ (5,32) IT
        IF (IT. EQ. 'X') GO TO 317
        DECODE (1,314, IT) L
        FORMAT (I1)
314
         IF (L. LE. O. OR. L. GE. 4) GO TO 317
        WRITE (5,315) LABEL(L)
        FORMAT ('$ENTER', AB, ' LY, SY, IY SEPARATED BY COMMAS: '
315
         1, ' [F] ')
        READ (5,316) (SCALYN(L,M), M=1,3)
316
        FORMAT (3F10.3)
         GD TD 310
317
        WRITE (5,318) LX,SX,IX
318
        FORMAT (' ', 10X, 'X-AXIS (TIME) SCALE FACTORS', //
         1,10X,7X,'LX',10X,7X,'SX',10X,7X,'IX',/
        2,(1X,'TN,BI MIN',3(F10.2,9X),/),/
         3, '$CHANGE X-AXIS? (Y/N) ')
         READ (5,32) IT
```

```
IF (IT. NE. 'Y') GO TO 320
        WRITE (5,319)
319
        FORMAT ('$ENTER LX,SX,IX SEPARATED BY COMMAS: [R] ')
         READ (5,316) LX,SX,IX
         GO TO 317
320
         IF (PLN. NE. 'Y') GO TO 360
         DO 350 K=1,2
         CALL NEWDEV (, 'DRO: COMPARN. VEC', 15)
         CALL PLOTST (4, 'IN', 1)
         CALL PLOT (1.0, 1.0, -3)
         CALL AXIS (0.0,0.0, 'TIME (MIN)',-10, LX, 0.0, SX, IX)
         GO TO (330,340) K
330
         LY=SCALYN(K, 1)
         SY=SCALYN(K, 2)
         IY=SCALYN(K, 3)
         LYS=LY
         CALL AXIS (0.0,0.0, 'NORMALIZED TEMPERATURE', +22, LY
         1,90.0,SY,IY)
         LABEL(1)='TN-EXPT '
         LABEL(2)='TN-PRED '
         OPEN (UNIT=6, NAME='DR: COMPARN. OUT')
         WRITE (6,331) BREG(BR), LY, SY, IY
         FORMAT (' ', 7X, 1AB, /, ' ', 7X, 'LY: ', F7. 2, 5X, 'SY: '
331
         1, F7. 2, 5X, 'IY: '
         2, F7. 2, /, ' ', 7X, '* INDICATES POINT NOT PLOTTED; '
         3, ' ITS VALUE IS <= 0 OR < SY', /
         4,12X, 'TIME ',13X, 'TN-EXPT ',10X
         5, ' TN-PRED ', /)
         CALL PLOTN(1, SYM)
         CALL PLOTND
         CLOSE (UNIT=6)
         GO TO 350
340
         LY=SCALYN(K, 1)
         SY=SCALYN(K, 2)
         IY=SCALYN(K, 3)
         LYS=LY
         CALL AXIS (O. O, O. O, 'BIOT NUMBER', +11, LY
         1,90.0,SY,IY)
         LABEL(1)='BI-EXPT '
         LABEL(2)='BI-PRED '
         OPEN (UNIT=6, NAME='DR: COMPARN. OUT')
         WRITE (6,341) BREG(BR), (PRT(M), M=1, LCL), LY, SY, IY
         FORMAT (' ',7X,1A8, <LCL>A1, /, ' ',7X, 'LY: ',F7. 2,5X, 'SY: '
341
         1, F7. 2, 5X, 'IY: '
         2,F7.2,/,' ',7X,'* INDICATES POINT NOT PLOTTED;'
         3, ' ITS VALUE IS <= 0 OR < SY', /
         4,12X, ' TIME ',13X, ' BI-EXPT ',10X
         5, ' BI-PRED ', /)
         CALL PLOTN(5, SYM)
         CALL PLOTND
         CLOSE (UNIT=6)
350
         CONTINUE
         IF (LO. EQ. 5) GO TO 361
360
```

CLOSE (UNIT=LO) 361 IF (ITOT. EQ. 0) QO TO 15 14 CONTINUE 15 CLOSE (UNIT=2, DISPOSE='SAVE') IF (REU. EQ. 'X') GO TO 362 GD TD 30 !THIS CALL TO A SYSTEM LEVEL SUBROUTINE IS !USED TO DE-ATTACH THE TERMINAL. SEE !COMMENT AT TOP OF CODE ABOUT INITIAL !CALL TO 'WTGIO' CALL WTGIO ("2000, "5) STOP END

```
FUNCTION REINIT(I)
         REAL A(5), B(5), C(9), D(9), E(9), F(9), G(9), H(9)
         COMMON /SUIT/A, C
         1. /MISC/E, G
         DATA B/1.63, 0.1175, 2.27, 0.15875, 0.17307/
         1, D/1. 0, 1. 0, 1. 0, 1. 0, 1. 0, 2. 0, 1. 0, 1. 0, 1. 0/
         2, F/23. 3, 60. 0, 49. 7, 42. 4, 85. 0, 97. 0, 98. 9, 125. 25
         3, 265. 86/
         4, H/2, 56, 2, 56, 2, 22, 3, 45, 3, 13, 12, 50, 2, 27, 2, 17, 3, 45/
         QD TD (10, 20, 30, 40) I
10
         DO 11 J=1,5
         A(J)=B(J)
11
         CONTINUE
         GO TO 100
20
         DO 21 J=1.9
         C(J)=D(J)
21
         CONTINUE
         GD TD 100
30
         DO 31 J=1,9
         E(J)=F(J)
31
         CONTINUE
         GD TO 100
40
         DO 41 J=1,9
         G(U)=H(U)
41
         CONTINUE
100
         REINIT=I
         RETURN
         END
```

REAL FUNCTION OHTC(SN) !THIS FUNCTION SYNTHESIZES THE PRESSURE AND TEMPERATURE !DATA AND PRODUCES A VALUE FOR THE OVERALL HEAT TRANSFER ! COEFFICIENT IN WATTS/SEC*C*(M**2) FOR THE GARMENT ! ENSEMBLE. !THE GARMENT ASSUMED IS THE NAVY'S DIVER THERMAL !PROTECTION ENSEMBLE !THE UNDERGARMENT IS MODELED AS DESCRIBED IN THE TEXT. !THE OUTER GARMENT IS MODELED AS A SOLID SLAB OF !NEOPRENE OF THICKNESS EQUAL TO OUTER GARMENT THICKNESS. !THE HEAT TRANSFER COEFFICIENT FOR THE OUTER BOUNDARY !LAYER IS DETERMINED FROM EQUATIONS DERIVED FROM !EXPERIMENTAL DATA. (SEE TEXT FOR DETAILS) C DHTC VARIABLES DEFINED IN MODULE OHTC !RDS = REGIONAL DATUM START=> REGION DEPTH BELOW SHOULDER REFERENCE (RDS=0.0 IF LAYING HORTIZONTAL) ! TCAR = THERMAL CONDUCTIVITY OF AIR AT REFERENCE TEMPERATURE OF 21.1 C AND A DEPTH OF ZERO METERS OF SEA WATER = 2.611E-2 WATTS/METER C = CONDUCTIVITY RATIO=> RATIO OF THERMAL ! CR CONDUCTIVITIES OF AIR AT 0 MSW, 21.1 C (TCAR) AND THE SUIT ENTRAPPED GAS AT AMBIENT DEPTH AND PRESSURE. = DECIMAL % CHANGE IN THINSULATE THICKNESS AS A ! DPCT FUNCTION OF HYDROSTATIC PRESSURE (DEPTH BELOW SHOULDERS) = NODAL DISTANCE INCREMENT. DISTANCE BETWEEN ! DZ NODES IN FINITE DIFFERENCE SOLUTION FOR EACH REGION. EACH CYLINDRICAL REGION IS DEVIDED INTO NODES ALLONG IT'S LENGTH ONLY. SPHERES ARE TREATED AS HAVING A SINGLE NODE AT ALL TIMES. DZV = NODAL DEPTH INCREMENT. DEPTH CHANGE CAUSED BY EACH NODE WHEN REGION IS VERTICAL. WHEN THE REGION IS HORTIZONTAL THE NODES STEP OUTWARD IN THE HORTIZONTAL DIRECTION. WHEN THE REGION IS VERTICAL THE NODES STEP DOWNWARD IN THE VERTICAL PLANE. !EDS = ELEMENT DISTANCE FROM SEA LEVEL, ELEMENT IMPLIES DIFFERENTIAL ELEMENT OF FINITE DIFFERENCE EQUATIONS. IE: DEPTH BELOW SEA LEVEL TO THE ELEMENT OF INTEREST) ! SEP = START OF NODAL ELEMENT POSITION, DISTANCE FROM THE STARTING END OF THE REGION TO THE START OF THE NODAL ELEMENT. ! SEPV - STARTING DEPTH OF THE NODAL ELEMENT FROM BEGINNING DEPTH OF THE REGION ! MT = MEAN TEMPERATURE BETW. AMBIENT AND THE SKIN

ESTIMATED TEMPERATURE OF THE GAS SURFACE. ENTRAPPED IN THE UNGERGARMENT. REFERENCE DEPTH (RD) CONVERTED TO METERS OF RDM SEA WATER. (RD => DEPTH FROM SEA LEVEL TO SHOULDERS > RED = REGIONAL ELEMENT DEPTH, DEPTH BELOW SHOULDERS TO MID-POINT OF THE ELEMENT OF INTEREST. (NOTE: IF SUBJECT LAYING HORTIZONTAL (ATT=2) THEN RED=0.0) = THERMAL RESISTANCE DUE TO THE PRESENCE OF THE ! ROBL BOUNDARY LAYER ON THE OUTSIDE SURFACE OF THE DUTER GARMENT = THERMAL RESISTANCE DUE TO THE PRESENCE OF THE ! RDG DUTER GARMENT = THERMAL RESISTANCE DUE TO THE PRESENCE OF THE ! RUG UNDER GARMENT = SPECIFIC RESISTANCE OF UNDER GARMENT ! SRO AT SEA LEVEL (CLO/CM) = SPECIFIC THERMAL RESISTANCE OF THE SRUGA UNDERGARMENT DUE TO THE ENTRAPPED GAS AT THE AMBIENT TEMPERATURE AND PRESSURE ONLY. SRUGHA = SPECIFIC THERMAL RESISTANCE OF THE UNDERGARMENT DUE TO BOTH HYDROSTATIC SQUEEZE AND THE AMBIENT GAS AT DEPTH RUCHA = THERMAL RESISTANCE OF THE UNDER GARMENT DUE TO BOTH HYDROSTATIC SQUEEZE AND THE AMBIENT GAS AT DEPTH (IN UNITS OF CLO'S) !RUGHAJ = THERMAL RESISTANCE OF THE UNDER GARMENT, RUCHA, CONVERTED FROM CLD'S TO SEC*C*M2/J OR C*M2/WATT = RADIUS FROM CENTER OF CYLINDER/SPHERE TO EDGE !R1 OF THE CYLINDER/SPHERE (M) = RADIUS FROM CENTER OF CYLINDER/SPHERE TO ! R2 OUTSIDE EDGE OF THE UNDERGARMENT (M) = RADIUS FROM CENTER OF CYLINDER/SPHERE TO ! R3 OUTSIDE EDGE OF OUTER GARMENT (M) = THICKNESS OF THE UNDERGARMENT, WUGO, AT DEPTH !TR2 THICKNESS REDUCED DUE TO HYDROSTATIC SQUEEZE = TEMPERATURE OF THE OUTER SURFACE OF THE ! T3 OF THE OUTER GARMENT !*NOTE* FLAG1,FTOL,TTOL,NTOL, AND REAL FUNCTION F ARE !ALL INVOLVED IN FINDING THE OUTSIDE SURFACE !TEMPERATURE, T3, OF THE OUTER GARMENT USING THE SECANT !METHOD OF FINDING THE REAL ROOTS OF THE FUNCTION F. = FLAG INDICATING RESULTS OF THE SECANT METHOD !FLAG1 FOR FINDING THE OUTSIDE SURFACE TEMP. OF THE DUTER GARMENT -3 => ESTIMATE OF OUTSIDE SURFACE TEMP. > OR = AMBIENT TEMPERATURE -2 => MAX ALLOWED NUMBER OF ITERATIONS , NTOL, EXCEEDED. -1 => VALUE OF FUNCTION F AT NEW TEMP.

EQUALS VALUE OF F AT OLD TEMP.

```
1 => COMPUTED CHANGE IN TEMPERATURE
                LESS THAN OR EQUAL TO MINIMUM ALLOWED
                TEMPERATURE SPECIFIED (TTOL).
           2 => NEW VALUE OF FUNCTION F LESS THAN OR
                EQUAL TO MINIMUM ALLOWED VALUE , FTOL.
!FTOL
        - MINIMUM ALLOWED VALUE OF THE FUNCTION F
! TTOL
        = MINIMUM ALLOWED VALUE FOR THE TEMPERATURE STEP
          AT EACH ITERATION
! NTOL
        = MAXIMUM ALLOWED NUMBER OF STEPS THE SECANT
          PROCEDURE CAN TAKE
! TN1
        = NEW ESTIMATE OF THE TEMPERATURE
        - OLD ESTIMATE OF THE TEMPERATURE
! TNO
        = DIFFERENCE BETW. OLD AND NEW TEMPERATURE
! DT
          ESTIMATES
: B
        = ARRAY CONTAINING BODY DIMENSIONS FOR THE 9
          REGION MODEL MAN.
! COR
        - ARRAY CONTAINING THE CORRESPONDENCE BETWEEN
          THE 9 REGION AND 12 SEGMENT MODELS
! WGT
        = ARRAY CONTAINING THE 12 SEGMENTAL HODY
          SURFACE AREA WEIGHTS.
! *NOTE*
         THE FOLLOWING VARIABLES USED IN THIS MODULE
!WERE DEFINED IN MODULE - MAIN
          ATT, BR, COG, DR, FLAG2, LO, NN, RD, RDU, SRO, TA,
          TDMS, WOC, WUGO, TWUGO
!*NOTE* THE FOLLOWING VARIABLES USED IN THIS MODULE
!ARE TEMPERARY VARIABLE AND HAVE NO PERMINANT MEANING
          I.N
INTEGER ATT, BR, SN, FLAG2, FLAG1, COR
REAL MT
BYTE RDU
COMMON /BODY/B(9,3), COR(9,2), WGT(12)
1,/DEBUG/FLAG2,LD
2, /OHTCD/RUGHA, RUG, ROG, ROBL, R1, R2, R3, T1, T3, FLAG1
3, Q1A, Q13
4, /PROB/BR, ATT, RD, RDM, TA, NN, TDMS, DZ, DZV, FLAG3, RDS
5, RDU
6,/SUIT/WUGO, DR, SRO, WDG, CDG, TWUGO(9)
!NTOL, FTOL, TTOL ARE TOLERANCE LIMITS USED IN FINDING
!T3 BY THE SECANT METHOD SUCH THAT F(T3)~=0:
!NTOL=> MAXIMUN NUMBER OF ITERATIONS ALLOWED
!FTOL=> ZERO TOLERANCE. IF F(T3) IS <= FTOL
        THEN F(T3)~=0
!TTOL=> ZERO TOLERANCE FOR THE DIFFERENCE BETWEEN
        T3(NEW) AND T3(OLD).
        IF (T3(NEW)-T3(OLD)) <= TTOL THEN DIFFERENCE IS
        ASSUMED ~= 0
DATA NTOL, FTOL, TTOL/300, 1. 0E-7, 1. 0E-3/
!TCAR = THERMAL CONDUCTIVITY OF AIR AT REFERENCE
```

CONDITIONS OF 21.1 C AND O MSW. (W/M*C)

DATA TCAR/2.611E-2/

```
RDS=0. 0
        RED=0. 0
        DPCT=0. 0
        IF (ATT. EQ. 2) GO TO 13 !2=PRONE
         ! ATT=0 DR ATT=1
                           (SIT, STAND)
        IF (BR. GT. 1) GO TO 10
        RDS=B(BR, 2)*(-1.0)
        GO TO 13
        IF (BR. EQ. 2) GO TO 13
10
        N=2
        IF (BR. GE. 7. AND. BR. LE. 9) N=7
11
        IF (BR. EQ. 7) GO TO 13
        DO 12 I=N, BR-1
        IF (I. EQ. 4. AND. ATT. EQ. 0) GO TO 110
        RDS=RDS+B(I,3)
        GO TO 12
110
        RDS=RDS+(B(I,2)/2,0)
12
        CONTINUE
         IF (BR. NE. 4. OR. ATT. NE. 0) GO TO 13
         !BR=4 AND ATT=0
        RDS=RDS-(B(BR,2)/2.0)
13
         IF (BR. NE. 1, AND. BR. NE. 9) GO TO 131
         !BR=1 OR BR=9
        DZ=B(BR, 2)
        SEP=0. 0
         SEPV=0. 0
         DZV=B(BR,2)
         IF (ATT. EQ. 2) DZV=0. 0
         GO TO 14
         DZ=B(BR,3)/FLOAT(NN)
131
         SEP=DZ*FLOAT(SN-1)
         DZV=B(BR, 3)/FLOAT(NN)
         IF (ATT. EQ. 2) DZV=0. 0
         IF (ATT. EQ. O. AND. BR. EQ. 4) DZV=B(BR, 2)
         SEPV=DZV*FLOAT(SN-1)
         IF (ATT. EQ. 2) SEPV=0.0
         IF (ATT. EQ. O. AND. BR. EQ. 4) SEPV=0. 0
14
         RDM=RD
         IF (RDU. NE. 'P') GO TO 15
                        !1.461 PSI/MSW
         RDM=RD/1.461
         IF (RDU. NE. 'F') GO TO 16
15
         RDM=RD*0. 3048
                                   10.3048 MSW/FSW
         IF (ATT. EQ. 2) GO TO 20
16
         RED=RDS+SEPV+DZV/2. 0
         IF (BR. EQ. 1) GO TO 20
         IF (RED. GT. O. 1711) GO TO 17
         DPCT=2. 358E-2*RED*100. 0
         GD TO 20
         !DPCT=>DECIMAL PERCENT CHANGE IN THICKNESS
                     THE MULTIPLICATION OF RED BY 100.0 IS TO
         ! **NOTE**
                     CONVERT THE UNITS FROM METERS TO CENTIMETERS
         DPCT=0.343+(3.784E-3*RED*100.0)-
17
```

f.

```
1(1.345E-5*((RED*100.0)**2))
        !TR=ESTIMATED REGIONAL TEMP. (12 POINT MODEL CONVERTED
           TO 9 POINT MODEL)
20
       MT = (T1 + TA)/2.0
       EDS=RDM+RED
        CR=TCAR/TC(MT, EDS)
                                !CONDUCTIVITY RATIO
21
        SRUGA=(SRO+CR)
        SRUGHA=SRUGA+(1.O-DR+DPCT)
        RUGHA=(SRUGHA*WUGO*TWUGO(BR))*(1.0-DPCT) !CLO'S
        ! ** NOTE **
        !RUGHA IS IN CLO'S
        !RUGHAJ IS RUGHA CONVERTED TO (SEC+C+M2/J)=(C+M2/WATT)
        RUGHAJ=RUGHA+0. 15477
                                10.15477 M2+C/WATT/CLU
        IF (FLAG2, EG. 0) GO TO 30
        WRITE (LO, 22) DZ, DZV, SEP, SEPV, RDM, RED, DPCT
        1, T1, MT, EDS, TCAR, TC (MT, EDS), CR
        2, SRUGA, SRUGHA, RUGHAJ
22
        FORMAT ('
                  DZ, DZV', 1P, 2G15. 7,/
            SEP, SEPV', 2015. 7, /
        2, ′
             RDM, RED, DPCT', 3G15. 7,/
             T1, MT, EDS ', 3G15. 7, /
        3, '
        4, 1
             TCAR, TC (MT, EDS) ', 2G15. 7, /, ' CR', G15. 7
        5, ′
             SRUGA, SRUGHA', 2G15. 7, /
             RUGHA', G15. 7, 'CLO RUGHAJ', G15. 7
        7, 'M2*C/WATT')
30
        R1=B(BR, 2)/2.0
        TR2=(WUGO+TWUGO(BR)+(1.0-DPCT))/100.0 !M
        R2=R1+TR2
                                !M
        R3=R2+(WDG/100.0)
                                !M
        RUG=R1*RUGHAJ*LOG(R2/R1)/TR2
                                        !M2*C/WATT
        ROG=R1*LOG(R3/R2)/COG
                                !M2*C/WATT
        ! USING SECANT METHOD TO FIND TEMPERATURE OF OUTSIDE
        ! SURFACE OF OUTER GARMENT (T3).
          ASSUME (T1+TA)/2.0 <= T3 <= TA
        ! TA+(TA*O.01) USED AS INITIAL END POINT, TO AVOID
        ! DETERMINATION OF 'GRPR' PRODUCT WHEN THE WALL
        ! TEMPERATURE = AMBIENT TEMPERATURE
        TNO=TA+(TA+0.01)
        ! *************
        TN1 = (T1 + TA)/2.0
        IF (TN1. LE. TA) QD TD 430
        N=1
        DT=TN1-TNO
40
        N=N+1
        IF (N. GT. NTOL) GO TO 45
        FO=F(TNO)
        F1=F(TN1)
```

```
IF (FLAG3. GT. O. O) RETURN
        IF (ABS(F1), LE, FTOL) QO TO 41
        IF ((F1-F0). EQ. 0. 0) QO TO 44
        DT=F1*DT/(F0-F1)
        TNO=TN1
        TN1=TN1+DT
        IF (TN1. LE. TA) QD TD 430
        IF (ABS(DT), LE, TTOL) GO TO 42
        GD TD 40
41
        FLAG1=2
                          !FTOL SATISFIED
        GD TD 43
42
        FLAG1=1
                          !TTOL SATISFIED
43
        T3=TN1
        IF (T3. GE. TA) GO TO 431
430
        FLAG1=-3
        GD TD 46
431
        ROBL=R1/(R3*CHTC(T3,R3))
        OHTC=1.0/(RUG+ROG+ROBL)
        GD TO 46
44
        FLAG1=-1
                                  !F(TN1)-F(TN0) < 0
        GO TO 46
45
        FLAG1=-2
                                  INTOL EXCEEDED
        IF (FLAG2. EQ. 0) QD TD 47
46
        TMP=F(TN1)
        WRITE (LO, 461) T3, DT, TN1, TMP, Q1A, Q13
461
        FORMAT (' T3, DT, TN1', 1P, 3Q15. 7, /
        1, ' F(TN1), Q1A, Q13', 3Q15.7)
47
        RETURN
        END
```

```
REAL FUNCTION F(T)
C F(T)
                VARIABLES DEFINE IN MODULE F(T)
        !THIS MODULE IS A FUNCTION SUBROUTINE DEFINING
        !THE FUNCTION TO BE SOLVED SUCH THAT F(T)~=0.
        !THE FUNCTION RELATES THE HEAT LOSS THRU THE
        !COMPLETE ENSEMBLE TO THAT THRU THE UNDER GARMENT
        !AND THE OUTER GARMENT. THE UNKNOWN IN THIS
        !EQUATION IS THE TEMPERATURE AT THE OUTSIDE
        !SURFACE OF THE OUTER GARMENT.
        !THE VALUE OF T3 PASSED AS T IS SUBSTITUTED INTO THE
        !EQUATION FOR F(T) AND THE CALCULATED VALUE IS
        !PASSED BACK FOR USE IN THE SECANT METHOD OF ESTIMATING
        ! T3
        VARIABLES NEEDED FOR CALCULATION OF F(T)
        ! C
                 = FUNCTION SUBROUTINE FOR CALCULATING THE
                   COEFFICIENT OF HEAT TRANSFER THRU THE FREE
                   CONVECTION BOUNDARY LAYER
                 = BODY REGION OF INTEREST, BR, PASSED TO THE
         ! IBR
                   SUBROUTINE
                 = THERMAL RESISTANCE OF DUTER GARMENT
         ! ROG
                 = THERMAL RESISTANCE OF UNDER GARMENT
        ! RUG
        ! T
                 = ARGUMENT PASSED TO FUNCTION, ESTIMATE
                   OF T3 TEMPERATURE OF OUTSIDE SURFACE OF
                   THE OUTER GARMENT
         !TA
                 = TEMPERATURE - AMBIENT
         !T1
                 = TEMPERATURE OF THE CYLINDER/SPHERE SURFACE
         ! T3
                 = TEMPERATURE OF THE OUTSIDE SURFACE OF THE
                   DUTER GARMENT
         !R1
                 = RADIUS TO REGION SURFACE/INNER GARMENT
                   INTERFACE
                 = RADIUS TO OUTER GARMENT/FLUID BOUNDARY LAYER
         !R3
                   INFERFACE
  *NOTE* THE FOLOWING VARIABLE ARE DEFINED IN PREVIOUS MODULES
        !DZ, DZV, FLAG1, IATT, NN, RD, RDU, RUGHA, R1, R2, R3, TDMS
        BYTE RDU
        INTEGER FLAG1
        COMMON /OHTCD/RUGHA, RUG, ROG, ROBL, R1, R2, R3, T1, T3, FLAG1
         1, Q1A, Q13
        2, /PROB/IBR, IATT, RD, RDM, TA, NN, TDMS, DZ, DZV, FLAG3, RDS
         3. RDU
        HC=CHTC(T,R3)
         IF (FLAG3. GT. O. O) RETURN
         Q1A=(T1-TA)/(RUG+RUG+(R1/(R3*HC)))
         Q13=(T1-T)/(RUG+ROG)
         F=Q1A-Q13
        RETURN
         END
```

```
REAL FUNCTION CHTC(T3,R3)
        !THIS FUNCTION COMPUTES THE CONVECTIVE HEAT TRANSFER
        !COEFFICIENT FOR THE OUTER BOUNDARY LAYER IN
        !WATTS/SEC*C*(M**2). THE EQUATIONS USED WERE
        !DERIVED FROM EXPERIMENTAL DATA. (SEE TEXT FOR DETAILS)
        INTEGER BR, COR, ATT, FLAG2, LO
        REAL LNU, LGRPR
        BYTE RDU
        COMMON /BODY/B(9,3), COR(9,2), WGT(12)
        1/PROB/BR, ATT, RD, RDM, TA, NN, TDMS, DZ, DZV, FLAG3, RDS
        2. RDU
        3,/DEBUG/FLAG2,LO
        !** NOTE **
        ! ALL REFERENCES TO LOG IMPLY LOG BASE 10 (LOG10)
        COEFFICIENTS FOR DETERMINATION OF THE GRASHOF AND
        !PRANDTL NUMBER PRODUCT.
        !USING:
                GRPR = (ALPHA)*(T WALL - T AMBIENT)*(L**3)
        ! WHERE:
                LOG (ALPHA) = BETA1*(LOG (T FILM))**BETA2
                ALPHA = G*BETA*RHO**2*CP/MU*K
                T FILM = (T WALL + T AMBIENT) / 2.0
                GRPR = GRASHOF# * PRANDTL#
        !THE COEFFICIENTS WERE FOUND BY FITTING THE EQUATION TO
        !EXPERIMENTAL DATA, SEE TEXT FOR DETAILS.
C
        COEFFICIENTS FOR DETERMINATION OF THE THERMAL
        !CONDUCTIVITY OF WATER AS A FUNCTION OF TEMPERATURE IN
        ! DEGREES C.
        !THE COEFFICIENTS WERE FOUND BY FITTING THE EQUATION TO
        !EXPERIMENTAL DATA, SEE TEXT FOR DETAILS.
        !K = CFO + CF1*T
        DATA BETA1, BETA2/9, 80714, 0, 12733/
        1, CFO, CF1/0, 56662, 1, 7977E-3/
        !COEFFICIENTS FOR DETERMINATION OF LOG (NU) AS A
        !FUNCTION OF LOG (GRPR) FOR VERTICAL CYLINDERS
        !LOG(NU) = VCO + VC1*(LOG(GRPR)) + VC2*((LOG(GRPR))**2)
        !THE COEFFICIENTS WERE FOUND BY FITTING THE EQUATION TO
        !EXPERIMENTAL DATA, SEE TEXT FOR DETAILS.
С
        COEFFICIENTS FOR DETERMINATION OF LOG (NU) AS A
        !FUNCTION OF LOG (GRPR) FOR SPHERES
        !LOG(NU) = SO*LOG(GRPR) + S1
        !THE COEFFICIENTS WERE FOUND BY FITTING THE EQUATION TO
        !EXPERIMENTAL DATA, SEE TEXT FOR DETAILS.
```

```
COEFFICIENTS FOR DETERMINATION OF LOG (NU) AS A
C
        !FUNCTION OF LOG (GRPR) FOR HORTIZONTAL CYLINDERS
        !LDG(NU) = HCO*LDG(GRPR) + HC1
        THE COEFFICIENTS WERE FOUND BY FITTING THE EQUATION TO
        !EXPERIMENTAL DATA, SEE TEXT FOR DETAILS.
        DATA VCO, VC1, VC2/9, 1934, -2, 4128, 0, 1817/
        1,50,51/0.46486,-1.9726/
        2, HCO, HC1/0, 2486, -0, 4483/
C CHTC
                VARIABLES DEFINED IN MODULE CHTC
        ! ALPHA
                = G*BETA*RHD**2*CP/MU*K
        ! BETA
                = LOG (ALPHA)
                = COEFFICIENT SEE ABOVE
        !BETA1
        !BETA2
                = COEFFICIENT SEE ABOVE
                = THERMAL CONDUCTIVITY OF WATER AT TEMPERATURE
        ! CF
                = COEFFICIENT SEE ABOVE
        !CFO
        !CF1
                = COEFFICIENT SEE ABOVE
                = CHARACTERISTIC LENGTH FOR FREE CONVECTION
        ! CL
                  FOR VERTICAL CYLINDERS = LENGTH OF CYLINDER
                   FOR HORTIZONTAL CYLINDERS = DIAMETER OF
                   CYLINDER
                   FOR SPHERES = DIAMETER
                 = GRASHOF NUMBER, PRANDTL NUMBER PRODUCT
         ! GR
                 = COEFFICIENT SEE ABOVE
         ! HCO
                = COEFFICIENT SEE ABOVE
         !HC1
         !LGRPR
                = LDG (GRPR)
                 = LOC (NU)
         !LNU
                   NU = NUSSELT NUMBER
         ! SO
                 = COEFFICIENT SEE ABOVE
                 = COEFFICIENT SEE ABOVE
         ! S1
                 = TEMPERATURE OF FILM
         !TF
                 = (T SURFACE + T AMBIENT GAS)/2.0
                 = COEFFICIENT SEE ABOVE
         ! VCO
                 = COEFFICIENT SEE ABOVE
         ! VC1
                 = COEFFICIENT SEE ABOVE
         !VC2
                 = ARRAY CONTAINING BODY REGION DIMENSIONS
         ! B
                 = INTEGER VARIABLE USED TO INDICATE SUCCESS OR
         !FLAG3
                   FAILURE OF THIS SUBROUTINE.
                         CHTC DETERMINED SUCCESSFULLY
                 = 0.0
                         CHTC NOT DETERMINED, ESTIMATED FILM
                 = 1.0
                         TEMPERATURE LESS THAN 1.0
                         CHTC NOT DETERMINED, GRASHOF*PRANDTL
                 = 2.0
                         PRODUCT IS EQUAL TO ZERO.
C *NOTE* THE FOLLOWING VARIABLES WERE DEFINED IN PREVIOUS
         ! MODULES:
         !BR, TA, T3
C *NOTE* ARRAYS COR AND WGT ARE PASSED TO THIS MODULE IN
         !LABELED COMMON BUT ARE NOT USED IN THIS MODULE.
         FLAG3=0. 0
```

```
GD TD (1,2) ATT
C
        ATT=0 SITTING
        GO TO (11, 10, 10, 12, 10, 10, 10, 10, 11) BR
C
        ATT=1 STANDING
1
        GO TO (11, 10, 10, 10, 10, 10, 10, 10, 11) BR
С
        ATT=2 PRONE
2
        QO TO (11, 12, 12, 12, 12, 12, 12, 12, 11) BR
        VERTICAL CYLINDERS
        CL=B(BR,3)
10
        ASSIGN 105 TO LRET
        GO TO 20
105
        LNU=VCO+(VC1*LGRPR)+(VC2*(LGRPR**2.0))
        GD TO 15
С
        SPHERE
11
        CL=2. 0*R3
        ASSIGN 115 TO LRET
        GO TO 20
115
        LNU=(SO*LGRPR)+S1
        GO TO 15
С
        HORTIZONTAL CYLINDER
12
        CL=2. 0*R3
                          ! M
        ASSIGN 125 TO LRET
        GO TO 20
125
        LNU=(HCO*LGRPR)+HC1
15
        CF=CFO+(CF1*TF)
                                   !W/M*C
        CHTC=(10.0**LNU)*CF/CL
                                  !W/M2*C
        RETURN
20
        TF=(T3+TA)/2.0
        IF (TF.LT. 1.0) GO TO 21
        BETA=BETA1*(LOG10(TF)**BETA2)
        ALPHA=(10.0**BETA)
        GRPR=ALPHA*(CL**3.0)*(T3-TA)
        IF (GRPR. LE. O. O) GO TO 23
        LGRPR=LOG10(GRPR)
        GO TO LRET
21
        WRITE (LD, 22)
        IF (LO. NE. 5) WRITE (5,22)
22
        FORMAT (' SYSTEM WILL NOT EXPONENTIATE A NEGATIVE ',/
         1, ' BASE BY A REAL EXPONENT', /
         2,20X, 'RUN TERMINATED !')
        FLAG3=1.0
        RETURN
23
         WRITE (LD, 24)
         IF (LO. NE. 5) WRITE (5, 24)
         FORMAT ( ' THE LOGARITHM OF ZERO '
24
         1, 'IS UNDEFINED', /
         2,20X, 'RUN TERMINATED !')
        FLAG3=2. 0
25
        RETURN
        END
```

REAL FUNCTION TC(TDC, Z) !THE FUNCTION SUBROUTINE TC(TDC, Z) DETERMINES THE !THERMAL CONDUCTIVITY OF AIR OR A SPECIFIED BREATHING !GAS MIXTURE CORRESPONDING TO THE VALUES !OF TEMPERATURE, T C, AND PRESSURE, Z MSW PASSED. !THE AIR VALUE IS DETERMINED BY A METHOD OF TWO !DIMENSIONAL LINEAR INTERPOLATION ADAPTED FROM !CARNAHAN, LUTHER, AND WILKES, "APPLIED NUMERICAL !METHODS", P 63, PRB 1.28, JOHN WILEY & SONS, INC., 1969 !THE MIXTURE THERMAL CONDUCTIVITY IS DETERMINED BY !CALLING FUNCTION TCMG. (SEE TCMG FOR DETAILS) ARRAY C - CONTAINS THERMAL CONDUCTIVITY DATA FOR AIR AT - PRESSURES - 14.7,30.0,50.0,100.0,200.0 PSIA - TEMPERATURES - 30. 0, 50. 0, 70. 0, 90. 0, 110. 0, 130.0 F **NOTE** CONDUCTIVITIES HAVE UNITS BTU/SEC FT F AND VALUES MUST BE MULTIPLIED BY 1.0E-06 DATA TAKEN FROM: - U.S. NAVY DIVING GAS MANUAL, - NAVSHIPS 0994-003-7010, 1971 - PAGE T-4 (AIR DATA) !LAYOUT OF ARRAY C 130.0 50.0 70.0 90.0 110.0 130.0 F 4.06 4.19 4, 32 4, 45 4, 58 ! 14. 7 ¦3. 93 :30.0 13. 93 4. 07 4. 20 4. 33 4. 46 4. 59 13. 95 4.08 4. 21 4, 34 4, 47 4, 59 ! 50. 0 4, 37 4, 49 4, 62 1100.0 13.98 4. 11 4. 24 1200.0 14.03 4. 29 4, 42 4, 54 4, 66 4. 16 ! Psia C*NOTE* IF THE VALUE OF 'C' RETURNED TO CALLING MODULE IS !NEGATIVE THEN THE VALUE OF 'T' OR 'Z' WAS OUT OF !RANGE FOR THE TABLE STORED IN ARRAY C. C TC VARIABLES REQUIRED AND LOCALLY DEFINED = TEMPERATURE OF INTEREST IN DEGREES C ! TDC ! Z = DEPTH BELOW SURFACE IN METERS OF SEAWATER = COMPONENT OF EQUATION FOR TC ! A (SINGLE TERM COMPUTED SEPARATELY) = COMPONENT OF EQUATION FOR TC ! B (SINGLE TERM COMPUTED SEPARATELY) = LOGICAL UNIT NUMBER AT WHICH TO PRINT ! LO INFORMATION. = ABSOLUTE PRESSURE => DEPTH IN METERS OF !P SEAWATER, Z. CONVERTED TO PSIA = TEMPERATURE DEGREES F => TEMPERATURE ! T DEGREES C. TDC. CONVERTED TO DEGREES F NOTE: VARIABLES I, II, IJ AND J ARE TEMPORARY VARIABLES USED AS DO LOOP INDICES AND COUNTERS.

```
BYTE IG
         INTEGER FLAG2
         REAL C(6,7)
         COMMON /DEBUG/FLAG2, LO
         2,/TRNOSQ/YG,IG
         DATA C/O. 0, 14. 7, 30. 0, 50. 0, 100. 0, 200. 0
         2, 30, 0, 3, 93, 3, 93, 3, 95, 3, 98, 4, 03
         3, 50. 0, 4. 06, 4. 07, 4. 08, 4. 11, 4. 16
         4, 70. 0, 4. 19, 4. 20, 4. 21, 4. 24, 4. 29
         5, 90, 0, 4, 32, 4, 33, 4, 34, 4, 37, 4, 42
         6, 110. 0, 4. 45, 4. 46, 4. 47, 4. 49, 4. 54
         7, 130. 0, 4. 58, 4. 59, 4. 59, 4. 62, 4. 66/
C
         CONVERT Z METERS OF SEA WATER TO PSI ABSOLUTE
         P=((64.15*100.0*Z)/(2.54*(12.0**3)))+14.7
C
         REDUCE P TO 1 SIGNIFICANT DIGIT AFTER DECIMAL PT
         P=((AINT((P+0.05)*10.0))/10.0)
C
         CONVERT DEGREES C TO F
         T=(((TDC+273.15)*1.8)-459.67)
         IF (IG. NE. 'A') GD TD 100
         IF (P. LT. C(2, 1), DR. T. LT. C(1, 2)
         1. OR. P. GT. C(6, 1). OR. T. GT. C(1, 7)) GO TO 20
         DO 10 I=2,6
         IF (C(I,1), LT.P) GO TO 10
         II=I
         IF (C(I,1), NE, P) II=II-1
         GO TO 12
10
         CONTINUE
         GD TD 20
         DO 13 J=2,7
12
         IF (C(1, J), LT, T) GD TD 13
         IJ=J
         IF (C(1, J). NE. T) IJ=IJ-1
         GD TD 15
         CONTINUE
13
         GO TO 20
15
         B=(T-C(1,IJ))/(C(1,IJ+1)-C(1,IJ))
         IF (T. EQ. C(1, IJ)) B=0.0
         A=(P-C(II,1))/(C(II+1,1)-C(II,1))
         IF (P. EQ. C(II, 1)) A=Q. Q
         TC=((1.O-A)*(1.O-B)*C(II,IJ))+(A*(1.O-B)*C(II+1,IJ))
         1+(B*(1.O-A)*C(II, IJ+1))+(A*B*C(II+1, IJ+1))
         CORRECT TO TO BE IN WATTS/M#C
         1.0E-6 IS APPLIED TO YIELD CORRECT VALUES
         TC=TC*(1.0E-6)*6230.551
C
         6230.551 J/M*C/BTU/FT*F
C
         RETURN
20
         TC=0. 0
         WRITE(LO, 11) T,P
         FORMAT ( ' ', 10X, 'T=', F10, 2, ' OR P=', F10, 2
11
         1, ' OUT OF RANGE OF TABLE')
         RETURN
```

TC≂TCMG(T,P)
RETURN
END

į

```
FUNCTION TCMG(T,P)
  THIS FUNCTION CALCULATES THE THERMAL CONDUCTIVITY OF A
  MIXTURE OF HELIUM AND DXYGEN OR NITROGEN AND DXYGEN
  BY USING THE MASON-SAXENA FORM OF THE WASSILJEWA
  EQUATION FOR THE THERMAL CONDUCTIVITY OF A BINARY MIXTURE.
  THE PURE GAS THERMAL CONDUCTIVITIES AND VISCOSITIES
  NECESSARY TO COMPUTE THE MIXTURE THERMAL CONDUCTIVITY
  ARE DEFINE IN THE FUNCTION INTERP. THESE TABLES ARE
  TAKEN FROM THE U. S. NAVY GAS MANUAL.
        INTEGER FL1, FL2, FLAG2
        BYTE IG, ANS
        REAL INTERP, TP(2,2), PHI(2), MW(3), KM, NUM, DENOM
        COMMON /DEBUG/FLAG2, LO
        2,/TRNOSQ/YG,IG
        DATA MW/28, 00, 4, 00, 32, 00/
        Y0=1.00-YG
        IF (IG. EQ. 'N')FL1=1
        IF (IG. EQ. 'H')FL1=2
  DETERMINE THERM. COND. AND VISCOSITY OF INERT
  GAS COMPONENT OF THE MIXTURE.
        DO 50 FL2=1,2
        TP(1, FL2) = INTERP(T, P, FL1, FL2)
        IF (TP(1,FL2), EQ. 0, 00) QO TO 1002
50
        CONTINUE
C
  DETERMINE THERM. COND. AND VISCOSITY OF
   DXYGEN COMPONENT OF THE MIXTURE.
        DO 60 FL2=1,2
        TP(2, FL2) = INTERP(T, P, 3, FL2)
        IF (TP(2,FL2), EQ. 0. 0) GD TD 1002
60
        CONTINUE
C
C
C
   GAS PROPERTY ARRAY FOR THE COMPONENT GASES USED TO
   COMPUTE THE BINARY BREATHING MIXTURE THERMAL
   CONDUCTIVITY KM:
C
C
                     THERMAL
                                            ABSOLUTE
C
                     CONDUCTIVITY
                                            VISCOSITY
C
                     BTU/S*FT*F
                                            LBM/S*FT
C
C
C
        INERT CAS
                     TP(1,1)
                                            TP(1,2)
C
        DXYGEN
                     TP(2,1)
                                            TP(2,2)
C
                *******
C
C
   MASON-SAXENA FORM OF WASSILJEWA'S EQUATION
   IS APPLIED TO THE COMPUTATION OF A BINARY
```

```
THIS TECHNIQUE
  BREATHING GAS MIXTURE.
  MAY ALSO BE DEVELOPED FOR USE WITH THE
  COMPUTATION OF THERMAL CONDUCTIVITY OF
   A TRI-MIXTURE OF BREATHING GASES.
C
  FOR A BINARY GAS MIXTURE, INDEX 1 REFERS TO
C
   INERT GAS IN THE PHI TERM CALCULATION
   AND 2 REFERS TO DXYGEN PROPERTY TERMS.
   THE TWO PHI TERMS ARE CONTAINED IN THE
C
   ARRAY NAMED PHI. CALCULATE PHI TERMS:
C
C
63
        NUM=(1.0+SQRT(TP(1,2)/TP(2,2))+((MW(3)/MW(FL1))++.25))++2
        DENOM=SGRT(8.0*(1.0+(MW(FL1)/MW(3))))
        PHI(1)=NUM/DENOM
        PHI(2)=(TP(2,2)/TP(1,2))*(MW(FL1)/MW(3))*PHI(1)
   THE THERMAL CONDUCTIVITY EXPRESSION (KM) OF A BINARY
   GAS MIXTURE IS COMPRISED OF TWO TERMS WHICH ARE
   DESIGNATED AS C1 AND C2.
                             KM IS DETERMINED BY
   SUMMING THE TWO TERMS C1 AND C2.
        C1=TP(1,1)/(1.0+(1.065*PHI(1)*(YD/YG)))
        C2=TP(2,1)/(1.0+(1.065*PHI(2)*(YG/YD)))
        KM=C1+C2
        TCMG=KM+6230. 551
   THE COMPUTED GAS MIXTURE THERMAL CONDUCTIVITY
   HAS BEEN CONVERTED FROM THE UNITS OF BTU/S*FT*F TO
   WATTS/M*C OR J/S*M*C.
                          6230.551 \text{ J/S*M*C} = 1 \text{ BTU/S*FT*F}
   THE SYMBOL TCMG HAS BEEN USED FOR RETURNING THE
   GAS MIXTURE THERMAL CONDUCTIVITY TO THE REAL FUNCTION
C
   SUBROUTINE TO
C
1002
        CONTINUE
        RETURN
        END
```

```
REAL FUNCTION INTERP(T, P, FL1, FL2)
   THIS FUNCTION SUBROUTINE INTERPOLATES COMPONENT GAS DATA
   TABULATED AS A FUNCTION OF TEMPERATURE IN DEGREES F
   AND PRESSURE IN PSIA.
                               DATA IS TABULATED FROM THE
   U.S. NAVY GAS MANUAL.
          REAL TCN(10,7), TCH(10,7), TCD(10,7), MUN(10,7)
          1, MUH(10, 7), MUB(10, 7), MF(2), DA(10, 7)
          INTEGER FL1, FL2, FLAG2
          COMMON /DEBUG/FLAG2, LO
          2,/TRNOSQ/YG,IG
 UNITS ARE AS FOLLOWS:
C THERMAL CONDUCTIVITY: BTU/SEC*FT*F
 ABSOLUTE VISCOSITY: LBM/FT*SEC
  THE RESULTS OF THIS PROGRAM SHOULD ALSO HANDLE TRI-MIXTURES OF
  NITROGEN, HELIUM AND DXYGEN.
  ARRAYS ARE ENTERED IN COLUMN MAJOR ORDER OF THE TABLES.
          DATA TCN/0., 14. 7, 30., 50., 100., 200., 300., 400., 500., 1000.
          1, 30. 0, 3. 834, 3. 84, 3. 86, 3. 89, 3. 95, 4. 01, 4. 08, 4. 14, 4. 48
          2, 50. 0, 3. 967, 3. 98, 3. 99, 4. 02, 4. 08, 4. 14, 4. 20, 4. 26, 4. 58
          3, 70. 0, 4. 100, 4. 11, 4. 12, 4. 15, 4. 21, 4. 26, 4. 32, 4. 38, 4. 68
          4, 90. 0, 4. 227, 4. 24, 4. 25, 4. 27, 4. 33, 4. 38, 4. 44, 4. 49, 4. 78
          5, 110. 0, 4. 348, 4. 36, 4. 37, 4. 39, 4. 45, 4. 50, 4. 55, 4. 60, 4. 88
          6, 130. 0, 4, 470, 4, 48, 4, 49, 4, 51, 4, 56, 4, 62, 4, 67, 4, 72, 4, 98/
          DATA TCH/0., 14. 7, 30., 50., 100., 200., 300., 400., 500., 1000.
          1, 30, 0, 2, 26, 2, 27, 2, 27, 2, 28, 2, 29, 2, 30, 2, 31, 2, 33, 2, 39
          2, 50. 0, 3*2. 32, 2. 33, 2. 34, 2. 36, 2. 37, 2. 38, 2. 45
          3, 70. 0, 2. 38, 2. 38, 2. 38, 2. 39, 2. 40, 2. 41, 2. 43, 2. 44, 2. 50
          4, 90. 0, 2*2. 43, 2. 44, 2. 44, 2. 45, 2. 47, 2. 48, 2. 49, 2. 55
          5, 110. 0, 2, 49, 2, 49, 2, 49, 2, 50, 2, 51, 2, 52, 2, 53, 2, 55, 2, 61
          6, 130. 0, 3*2. 54, 2. 55, 2. 56, 2. 57, 2. 59, 2. 60, 2. 66/
          DATA TCD/0., 14.7, 30., 50., 100., 200., 300., 400., 500., 1000.
          1, 30. 0, 3. 918, 3. 93, 3. 94, 3. 97, 4. 03, 4. 09, 4. 15, 4. 21, 4. 54
          2, 50. 0, 4. 068, 4. 08, 4. 07, 4. 12, 4. 17, 4. 23, 4. 27, 4. 35, 4. 66
          3, 70. 0, 4. 214, 4. 22, 4. 23, 4. 26, 4. 32, 4. 37, 4. 43, 4. 48, 4. 79
          4, 90. 0, 4. 353, 4. 36, 4. 37, 4. 40, 4. 45, 4. 50, 4. 56, 4. 61, 4. 89
          5, 110. 0, 4, 483, 4, 49, 4, 50, 4, 53, 4, 58, 4, 63, 4, 68, 4, 73, 4, 99
          6, 130. 0, 4, 611, 4, 62, 4, 63, 4, 65, 4, 70, 4, 75, 4, 80, 4, 85, 5, 10/
```

```
DATA MUN/0., 14.7, 30., 50., 100., 200., 300., 400., 500., 1000.
         1, 30, 0, 1, 114, 1, 12, 1, 12, 1, 12, 1, 13, 1, 14, 1, 15, 1, 16, 1, 22
         2, 50. 0, 1. 148, 1. 15, 1. 15, 2*1. 16, 1. 17, 1. 18, 1. 19, 1. 25
         3, 70. 0, 1. 184, 3+1. 19, 1. 20, 1. 21, 1. 22, 1. 22, 1. 28
          4, 90. 0, 1. 219, 2*1. 22, 2*1. 23, 1. 24, 1. 25, 1. 26, 1. 31
          5, 110, 0, 1, 255, 3*1, 26, 1, 27, 1, 28, 1, 28, 1, 29, 1, 34
          6, 130, 0, 1, 289, 2*1, 29, 2*1, 30, 1, 31, 1, 32, 1, 33, 1, 37/
C
         DATA MUH/O. 114. 7, 30. , 50. , 100. , 200. , 300. , 400. , 500. , 1000.
          1,30.0,9*1.257
         2,50.0,9*1.290
         3,70.0,9*1.323
          4, 90. 0, 9*1. 357
          5, 110. 0, 9*1. 389
          6, 130, 0, 9*1, 422/
C
         DATA MUD/0., 14. 7, 30., 50., 100., 200., 300., 400., 500., 1000.
          1, 30, 0, 1, 281, 1, 28, 1, 28, 1, 29, 1, 30, 1, 31, 1, 32, 1, 34, 1, 40
          2, 50, 0, 1, 322, 1, 32, 1, 33, 1, 33, 1, 34, 1, 35, 1, 36, 1, 37, 1, 43
          3, 70. 0, 1. 364, 3*1. 37, 1. 38, 1. 39, 1. 40, 1. 41, 1. 46
          4, 90. 0, 1. 404, 3*1. 41, 1. 42, 1. 43, 1. 44, 1. 45, 1. 50
          5, 110. 0, 1. 440, 1. 44, 1. 44, 1. 45, 1. 46, 1. 46, 1. 47, 1. 48, 1. 54
          6, 130. 0, 1. 482, 2*1. 48, 1. 49, 1. 50, 2*1. 51, 1. 52, 1. 57/
C
         DATA MF/1. E-05, 1. E-06/
   SYMBOL DA STANDS FOR THE WORKING DATA ARRAY INTO
   WHICH SPECIFIC ARRAYS OF DATA ARE TRANSFERRED FOR PURPOSE
   OF INTERPOLATION.
          IF (FL1. EQ. 1. AND. FL2. EQ. 1) GO TO 30
          IF (FL1. EQ. 1. AND. FL2. EQ. 2) QO TO 31
          IF (FL1. EQ. 2. AND. FL2. EQ. 1) GO TO
          IF (FL1. EQ. 2. AND. FL2. EQ. 2) QO TO 33
          IF (FL1. EQ. 3. AND. FL2. EQ. 1) GO TO 34
          IF (FL1. EQ. 3. AND. FL2. EQ. 2) GD TO 35
30
          DO 40 J=1,7
          DO 40 I=1,10
          DA(I, J)=TCN(I, J)
40
          CONTINUE
          NM=1
          SF=MF(2)
          GO TO 61
31
          DO 41 J=1,7
          DO 41 I=1,10
          DA(I,J)=MUN(I,J)
41
          CONTINUE
          NM=4
          SF=MF(1)
          QO TO 61
32
          DO 42 J=1,7
          DO 42 I=1,10
          DA(I, J)=TCH(I, J)
```

```
42
        CONTINUE
        NM=2
        SF=MF(1)
        GO TO 61
33
        DO 43 J=1,7
        DO 43 I=1,10
        DA(I,J)=MUH(I,J)
43
        CONTINUE
        NM=5
        SF=MF(1)
        QO TO 61
34
        DO 44 J=1,7
        DO 44 I=1,10
        DA(I, J)=TCO(I, J)
        CONTINUE
44
        E≠MN
        SF=MF(2)
        GO TO 61
35
        DO 45 J=1,7
        DO 45 I=1,10
        DA(I,J)=MUO(I,J)
45
        CONTINUE
        NM=6
        SF=MF(1)
61
        CONTINUE
        IF (P. LT. DA(2, 1), OR. T. LT. DA(1, 2)
63
        1. OR. P. GT. DA(10, 1). OR. T. GT. DA(1, 7)) GO TO 20
        DO 10 I=2,10
        IF (DA(I,1), LT.P) QD TD 10
        II=I
        IF (DA(I, 1). NE. P) II=II-1
        GD TD 12
10
        CONTINUE
        GD TO 20
12
        DO 13 J=2.7
        IF (DA(1, J), LT, T) GO TO 13
         IJ=J
         IF (DA(1, J), NE, T) IJ=IJ-1
        GO TO 15
13
        CONTINUE
        GD TD 20
15
        B=(T-DA(1,IJ))/(DA(1,IJ+1)-DA(1,IJ))
         IF (T. EQ. DA(1, IJ)) B=0.0
         A=(P-DA(II,1))/(DA(II+1,1)-DA(II,1))
         IF (P. EQ. DA(II, 1)) A=0.0
         INTERP=((1.0-A)*(1.0-B)*DA(II,IJ))+
         1(A*(1.O-B)*DA(II+1,IJ))+
        2(B*(1.0-A)*DA(II,IJ+1))+
         3(A*B*DA(II+1,IJ+1))
         INTERP=INTERP+SF
        RETURN
C THIS IS SUBROUTINE BLOW-OUT STATEMENT.
```

REAL FUNCTION TR(TDMS, BR)

!THIS FUNCTION COMPUTES THE PREDICTED REGIONAL
!TEMPERATURES FOR THE 9 REGION MODEL.
!THE PREDICTIVE EQUATIONS USED WERE DERIVED FOR
!THE 12 SEGMENT HODY MODEL WITH EXPERIMENTAL
!DATA. (SEE TEXT FOR DETAILS)
!THE PREDICTIONS FOR THE 12 SEGMENTS WERE
!COMBINED BY A WEIGHTED SUM USING THE HODY
!WEIGHTS CORRESPONDING TO THE SUMMED SEGMENTS.
!THE CORRESPONDENCE BETWEEN THE 9 REGION AND 12 SEGMENT
!MODELS IS SHOWN IN ARRAY COR, BELOW. FOR MORE DETAIL
!SEE MODULE MAIN

!ROW#	9 REGIOM	12 SEGMENT MODEL
! =>BR	MODEL NAME	CORRESPONDING SEGMENTS NAME(ID#)
!		ID #'S ARE IN ARRAY COR(9,2)
! 1	HEAD	HEAD(1),(-1)
!2	TORSO	CHEAT(2), UPPER BACK(4)
!3	ABDOMEN	ABDOMEN(3), LOWER BACK(5)
! 4	THIGH	FRONT THIGH(8), REAR THIGH(10)
! 5	CALF	FRONT CALF(9), REAR CALF(11)
!6	FOOT	FOOT(12),(-1)
!7	UPPER ARM	ARM(6),(-1)
!8	LOWER ARM	ARM(6),(-1)
! 9	HAND	WRIST(7), (-1)
!		NOTE (-1) INDICATES THAT ONLY
!		ONE CORRESPONDING SEGMENT IS
!		AVAILABLE FROM 12 SEGMENT MODEL

C TR

VARIABLE REQUIRED AND LOCALLY DEFINED

!TDMS = DESIGN MEAN SKIN TEMPERATURE. MEAN ! SKIN TEMPERATURE AT WHICH TO COMPUTE ! THE PREDICTED REGIONAL TEMPERATURES.

!BR = BODY REGION OF INTEREST. ONE OF THE ! 9 REGION MODEL REGIONS.

!COR = ARRAY CONTAINING CORRESPONDENCE BETWEEN 9
! REGION AND 12 SEGMENT MAPS

SWGT = SUM OF WEIGHTS CORRESPONDING TO THE 12 SEGMENTS SUMMED.

!PRED = FUNCTION SUBROUTINE WHICH CALCULATES THE
! 12 SEGMENTAL PREDICTED TEMPERATURES AT
! A GIVEN MEAN SKIN TEMPERATURE, TDMS
! AND SEGMENT J

!WGT = ARRAY CONTAINING THE 12 HODY SURFACE WEIGHTS

NOTE: ARRAY B IS PASSED TO THIS MODULE IN LABELED COMMON BUT THIS ARRAY IS UNUSED IN THIS MODULE.

NOTE: VARIABLES I AND J ARE TEMPORARY VARIABLES USED AS DO LOOP INDICES AND COUNTERS.

! NOTE: VARIABLES I AND J ARE TEMPORARY VARIABLES USED

AS DO LOOP INDICIES AND COUNTERS.

```
INTEGER COR, BR
COMMON /BODY/B(9,3), COR(9,2), WGT(12)
TR=0. 0
SWGT=0. 0
        THERE IS NO CHECKING FOR O. O VALUES
! NOTE:
        IN THE SUM SINCE THE PREDICTED VALUES
        CAN NOT BE ZERO UNLESS TDMS=0. O.
        TDMS CAN NOT BE ZERO BY ACCIDENT IT
        MUST BE SPECIFIED AS ZERO IF THAT
        IS THE DESIRED VALUE.
DO 10 I=1,2
J=COR(BR, I)
IF (J. EQ. -1) GO TO 10
SWGT=SWGT+WGT(J)
TR=TR+(PRED(J, TDMS) +WGT(J))
CONTINUE
TR=TR/SWGT
RETURN
END
```

10

REAL FUNCTION PRED(REG, TSKM) !FUNCTION PRED DETERMINES THE PREDICTED 12 SEGMENTAL !TEMPERATURES FROM EQUATIONS DERIVED USING !EXPERIMENTAL DATA AND BASED ON A KERSLAKE !TYPE MODEL. (SEE TEXT FOR DETAILS) C PRED VARIABLES REQUIRED AND LOCALLY DEFINED - SEGMENT FOR WHICH TO PREDICT !REG SKIN TEMPERATURE = MEAN SKIN TEMPERATURE TO USE AS ! TSKM INDEPENDENT ARGUMENT IN THE EQUATIONS. USJALLY THE DESIGN MEAN SKIN TEMPERATURE. - ARRAY CONTAINING THE COEFFICIENTS FOR !KA THE PREDICTIVE EQUATIONS = CONSTANT USED IN THE PREDICTIVE EQUATIONS REAL KA, KR

REAL KA, KR
INTEGER REG
COMMON /PREDD/KA(12), KR
PRED=TSKM+(KA(REG)*KR)
RETURN
END

SUBROUTINE PLOTD(IR, PSYM, BR) !PLOTD IS A SUBROUTINE FOR PLOTTING T'S, Q'S, AND U'S BOTH PREDICTED AND EXPERIMENTAL VERSUS TIME. C PLOTD VARIABLES REQUIRED AND LOCALLY DEFINED ! IR = OFFSET INTO ARRAY P AT WHICH TO PICK UP BOTH THE PREDICTED AND EXPERIMENTAL DATA. P(ROW, IR+1) = EXPERIMENTAL P(ROW, IR+2) = PREDICTED PSYM = ARRAY (PSYM(2)) CONTAINING THE INTEGER NUMBERS INDICATING THE SYMBOLS TO BE USED FOR THE EXPERIMENTAL AND PREDICTED CURVES RESPECTIVELY. (SEE DIGITAL EQUIPMENT CORP. MANUAL PLXY-11M, USER'S GUIDE FOR DETAILS) BR = BODY REGION WHICH THE EXPERIMENTAL AND PREDICTED VALUE CORRESPOND TO. !LYS = Y-AXIS LEVEL FOR LABLES. INITIALLY SET AT LY ! NREC = NUMBER OF TIME RECORDS TO PLOT (IE: 1 TO NREC) = BYTE VARIABLE CONTAINING EITHER '*' OR ' ' (SPACE). IT IS USED TO FLAG THE EXPERIMENTAL DATA POINTS NOT PLOTED BECAUSE THEY ARE EITHER <= 0 OR < SY. SY IS THE STARTING VALUE FOR THE Y-AXIS. = BYTE VARIABLE CONATAINING EITHER '*' OR ' ' (SPACE). THIS VARIABLE IS USED IN THE SAME MANNER AS VARIABLE DE EXCEPT THAT DP IS USED FOR THE PREDICTED VALUES. BREG = ARRAY CONTAINING NAMES OF BODY REGIONS ARRANGED TO CORRESPOND TO BR = ARRAY CONTAINING LABEL TEXT FOR THE PLOTS ■ ARRAY CONTAINING THE DATA TO BE PLOTTED. NOTE: VARIABLES E, F, G, J, K AND L ARE TEMPORARY VARIABLES USED FOR DUMMY ARGUMENTS, DO LOOP INDICES AND COUNTERS. THE FOLLOWING VARIABLE ARE DEFINED IN A MANNER NECESSARY TO SATISFY THE DEC PLXY-11M SUBROUTINE'S SPECIFICATIONS ! IX = X-AXIS INCREMENT => # UNITS PER PLOT UNIT = Y-AXIS INCREMENT => # UNITS PER PLOT UNIT ! IY = X-AXIS LENGTH IN PLOT UNITS !LX !LY = Y-AXIS LENGTH IN PLOT UNITS !SX = X-AXIS STARTING VALUE = Y-AXIS STARTING VALUE !SY ≈ ARRAY USED TO PASS X-AXIS VALUES TO ! XP PLXY-11M SUBROUTINE LINE ! YP = ARRAY USED TO PASS Y-AXIS VALUES TO

PLXY-11M SUBROUTINE LINE REAL LX, SX, IX, LY, SY, IY, LYS, XP(125), YP(125) REAL*8 LABEL(3), BREG(10) INTEGER PSYM(2), BR BYTE LE, DP, REU, PRT COMMON /PLOT/P(125,9), LX, SX, IX, LY, SY, IY, LYS, LABEL, NREC 1, BREG, XP, YP, PD(125, 3), LCL, CH, REU, PRT(13) SL=3. 0 IF (CH. GT. O. O) SL=CH CALL SYMBOL (LX-SL, LYS-0. 20, 0. 1169, BREG(BR), 0. 0, +8) IF (IR. EQ. 1) GO TO 10 CALL SYMBOL (999.,999.,0.1169,PRT,0.0,+LCL) 10 CALL PLOT (0.0,0.0,+3) LYS=LYS-0. 20 DO 13 J=1,2 L=0 DO 12 K=1, NREC IF (J. GT. 1) GD TO 115 DE=' ' C CHECKING EXP'T VALUE TO BE IN RANGE OF PLOT IF (P(K, IR+1), LE. O. OR, P(K, IR+1), LT, SY) DE='*' DP=' ' C CHECKING PRED VALUES TO BE IN RANGE OF PLOT IF (P(K, IR+2), LE. O. OR, P(K, IR+2), LT, SY) DP='*' WRITE (6,11) P(K,1),P(K, IR+1),DE,P(K, IR+2),DP 11 FORMAT (10X, F8. 2, 10X, F10. 2, 1A1, 9X, F10. 2, 1A1) 115 IF (P(K,J+IR). LE. O. O. OR. P(K,J+IR). LT. SY) GO TO 12 L=L+1 XP(L)=P(K,1)YP(L)=P(K, J+IR)12 CONTINUE XP(L+1)=SXXP(L+2)=IXYP (L+1)=SY YP(L+2)=IYCALL PLOT (0.0,0.0,+3) CALL LINE (XP, YP, L, 1, +1, PSYM(J)) CALL SYMBOL (LX-SL, LYS-0. 20, 0. 1169, LABEL(J), Q. 0, +8) CALL WHERE (E,F,G) CALL SYMBOL (E,F+(0.1169/2.0), 0.1169, PSYM(J), 0.0,-1) CALL WHERE (E, LYS, G) LYS=LYS-(0.1169/2.0)

13

CONTINUE RETURN END

```
SUBROUTINE PLOTN(IR, PSYM)
        !PLOTN IS A SUBROUTINE FOR PLOTTING NORMALIZED
        !TEMPERATURES AND BIOT NUMBERS
        !BOTH PREDICTED AND EXPERIMENTAL VERSUS TIME.
C PLOTN
                VARIABLES REQUIRED AND LOCALLY DEFINED
        ! IR
                = OFFSET INTO ARRAY P AT WHICH TO PICK
                  UP BOTH THE PREDICTED AND EXPERIMENTAL DATA.
                  P(ROW, IR+1) = EXPERIMENTAL
                  P(ROW, IR+2) = PREDICTED
          PSYM = ARRAY ( PSYM(2) ) CONTAINING THE INTEGER
                  NUMBERS INDICATING THE SYMBOLS TO BE USED FOR
                  THE EXPERIMENTAL AND PREDICTED CURVES
                  RESPECTIVELY. (SEE DIGITAL EQUIPMENT CORP.
                  MANUAL PLXY-11M, USER'S GUIDE FOR DETAILS)
          BR
                = BODY REGION WHICH THE EXPERIMENTAL AND
                  PREDICTED VALUE CORRESPOND TO.
                = DEPTH IN MSW TO THE MIDDLE OF THE REGION.
        ! RMD
                = Y-AXIS LEVEL FOR LABLES. INITIALLY SET
        !LYS
                  AT LY
                = NUMBER OF TIME RECORDS TO PLOT
        ! NREC
                   (IE: 1 TO NREC)
        ! DE
                = BYTE VARIABLE CONTAINING EITHER '*'
                  OR ' ' (SPACE). IT IS USED TO FLAG
                  THE EXPERIMENTAL DATA POINTS NOT
                  PLOTED BECAUSE THEY ARE EITHER <= 0 OR
                         SY IS THE STARTING VALUE
                   < SY.
                  FOR THE Y-AXIS.
                = BYTE VARIABLE CONATAINING EITHER '*'
        ! DP
                   OR ' ' (SPACE). THIS VARIABLE IS USED
                   IN THE SAME MANNER AS VARIABLE DE
                   EXCEPT THAT DP IS USED FOR THE PREDICTED
                   VALUES.
                = ARRAY CONTAINING NAMES OF BODY REGIONS
         BREG
                   ARRANGED TO CORRESPOND TO BR
                = ARRAY CONTAINING LABEL TEXT FOR THE PLOTS
         LABEL
                = ARRAY CONTAINING THE DATA TO BE PLOTTED
          NOTE: VARIABLES E, F, G, J, K AND L ARE TEMPORARY
                VARIABLES USED FOR DUMMY ARGUMENTS,
                DO LOOP INDICES AND COUNTERS.
                 THE FOLLOWING VARIABLE ARE DEFINED IN
          NOTE:
                   A MANNER NECESSARY TO SATISFY THE DEC
                   PLXY-11M SUBROUTINE'S SPECIFICATIONS
                 = X-AXIS INCREMENT => # UNITS PER PLOT UNIT
         ! IX
                 = Y-AXIS INCREMENT => # UNITS PER PLOT UNIT
         ! IY
                 = X-AXIS LENGTH IN PLOT UNITS
         !LX
         !LY
                 = Y-AXIS LENGTH IN PLOT UNITS
         !SX
                 = X-AXIS STARTING VALUE
         ! SY
                 = Y-AXIS STARTING VALUE
         ! XP
                 = ARRAY USED TO PASS X-AXIS VALUES TO
```

```
PLXY-11M SUBROUTINE LINE
                 = ARRAY USED TO PASS Y-AXIS VALUES TO
        ! YP
                   PLXY-11M SUBROUTINE LINE
        REAL LX, SX, IX, LY, SY, IY, LYS, XP(125), YP(125)
        REAL*8 LABEL(3), BREG(10)
        INTEGER PSYM(2), BR, ATT, COR
        BYTE DE, DP, RDU, REU, PRT
        COMMON /BODY/B(9,3), COR(9,2), WGT(12)
        1, /PROB/BR, ATT, RD, RDM, TA, NN, TDMS, DZ, DZV, FLAG3, RDS
        2, RDU
        3, /PLOT/P(125, 9), LX, SX, IX, LY, SY, IY, LYS, LABEL, NREC
        4, BREG, XP, YP, PD(125, 3), LCL, CH, REU, PRT(13)
        SL=3.0
        IF (CH. GT. O. O) SL=CH
        CALL SYMBOL (LX-SL, LYS-0. 20, 0. 1169, BREG(BR), 0. 0, +8)
         IF (IR. EQ. 1) GO TO 10
        CALL SYMBOL (999., 999., 0.1169, PRT, 0.0, +LCL)
         CALL PLOT (0.0,0.0,+3)
10
        LYS=LYS-0. 20
         IF (ATT, EQ. 2) RMD=RDM
         IF (ATT, EQ. 1) RMD=RDM+RDS+(B(BR, 3)/2.0)
         IF (ATT, NE. 0) GO TO 5
        RMD=RDM+RDS
         IF (BR. EQ. 4) RMD=RMD+(B(BR, 2)/2.0)
         IF (BR. NE. 4) RMD=RMD+(B(BR, 3)/2.0)
         DO 13 J=1,2
5
         L=0
         DO 12 K=1, NREC
         CHECKING EXP'T VALUE TO BE IN RANGE OF PLOT
C
         IF (P(K, 1+IR), LE. O. O. OR. P(K, 1+IR), LT. SY) GO TO 12
         L=L+1
         XP(L)=P(K, 1)
         PD(L,1)=XP(L)
         IF (IR. NE. 1) GO TO 11
         YP(L)=(P(K, J+IR)-P(K, 9))/(P(K, 8)-P(K, 9))
         PD(L, J+1)=YP(L)
         GO TO 12
         IF (IR. NE. 5) GO TO 12
11
         TM=(P(K,J+1)+P(K,9))/2.0
         YP(L)=(P(K,J+IR)*(B(BR,2))/2.0)/TC(TM,RMD)
         PD(L, J+1)=YP(L)
         CONTINUE
12
         XP(L+1)=SX
         XP(L+2)=IX
         YP (L+1)=SY
         YP(L+2)=IY
         CALL PLOT (0.0,0.0,+3)
         CALL LINE (XP, YP, L, 1, +1, PSYM(J))
         CALL SYMBOL (LX-SL, LYS-0. 20, 0. 1169, LABEL (J), 0. 0, +B)
         CALL WHERE (E,F,G)
         CALL SYMBOL (E, F+(0. 1169/2. 0), 0. 1169, PSYM(J), 0. 0, -1)
         CALL WHERE (E, LYS, G)
```

LYS=LYS-(0.1169/2.0)

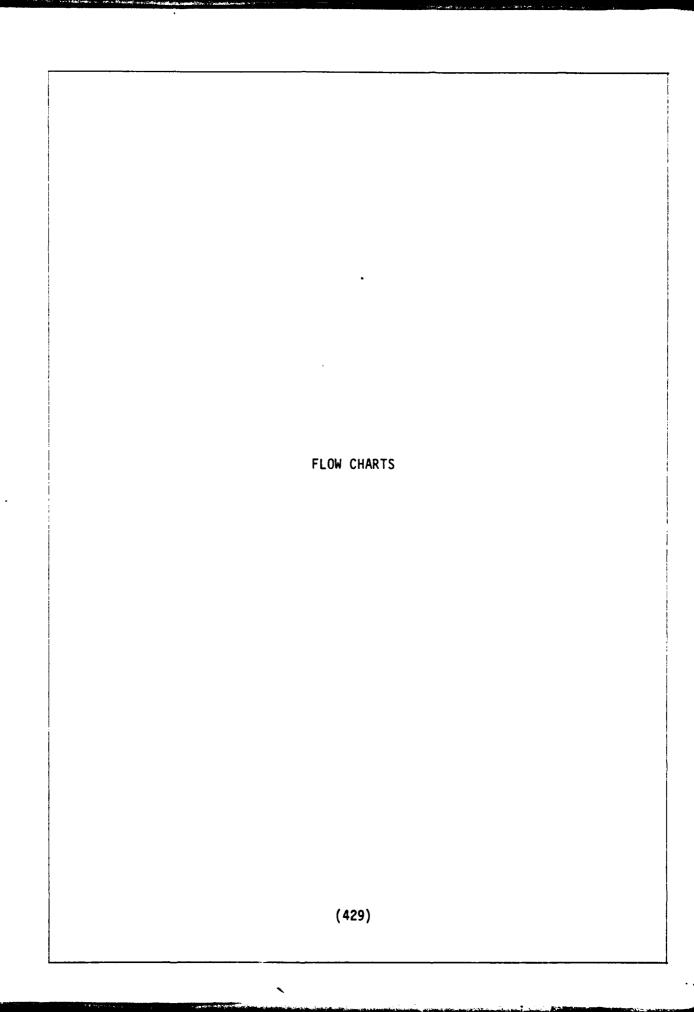
CONTINUE 13

WRITE (6,14) (PD(K,1),PD(K,2),PD(K,3),K=1,L) FORMAT (10X,F8.2,10X,F10.2,10X,F10.2)

14

RETURN

END



This function determines whether the breathing gas is air, a mixture of helium and oxygen, or a mixture of nitrogen and oxygen. If the breathing gas is air, its thermal conductivity is determined within this function. If the gas is either of the mixtures, the function TCMG is called to determine the mixture thermal conductivity.

Declare passed variables.

Convert TDC °C to T °F and convert Z MSW to P PSIA.

Branch to the appropriate statement for a breathing gas of air (IG = 'A'), or a mixture which contains nitrogen (IG = 'N') or helium (IG = 'H').

IF IG ≠ 'A' GO TO A

Compute the thermal conductivity of air (TC) at a temperature of T °F and a pressure of P PSIA from a table of data extracted from the U.S. Navy Diving Gas Manual [2]. A method of two-dimensional linear interpolation described by Carnahan, Luther, and Wilkes, Applied Numerical Methods, p. 63 [3] is used. The table of air data covers a temperature range of -1.11 to 54.44 °C and a pressure range of 14.7 to 200.0 PSIA (1.0 to 13.6 ATA).

RETURN

A Calculate the mixed gas thermal conductivity (See Functions TCMG and INTERP.) by:

TC = TCMG(T,P)

RETURN

Function TCMG(T,P)

Declare passed (in common) variables YG as real and IG as byte.

Determine the mole fraction for oxygen (YO) by:

Y0 = 1.00 - YG

YG = Inert gas (helium or nitrogen) mole fraction.

Determine the thermal conductivity and absolute viscosity of the pure components (helium and oxygen, or nitrogen and oxygen) by calling real function subroutine INTERP. Store these values in Array TP.

Determine the thermal conductivity of the breathing gas mixture (TCMG) by the Mason-Saxena form or Wassiljewa's equation as a function of temperature (T), pressure (P), thermo-physical property array (TP), molecular weight of the components (Array MW), and the mole fractions (YG and YO). The units of TCMG are BTU/FT·SEC·°F.

Convert the units of TCMG to W/M°C.

This function determines the thermal conductivity (FL2=1) or the absolute viscosity (FL2=2) of the pure gases nitrogen (FL1=1), helium (FL1=2), and oxygen (FL1=3) at a temperature of T °F and pressure of P PSIA. The thermal conductivity (BTU/FT-SEC°F) and absolute viscosity (LBM/FT-SEC) are determined from tables of data excerpted from the U.S. Navy Diving Gas Manual [2]. A method of two-dimensional Tinear interpolation described by Carnahan, Luther, and Wilkes, Applied Numerical Methods, p. 63 [3] is used. The tabulated data spans a temperature range of 30 °F (-1.11 °C) to 130 °F (54.44 °C) and a pressure range of 14.7 to 1000.0 PSIA (1.0 to 68.0 ATA).

Copy the appropriate pure component absolute viscosity (FL2=2) or thermal conductivity (FL2=1) data array into the working array DA.

Interpolate as described above for the value (INTERP) from the data of Array DA at a temperature of T °F and a pressure of P PSIA in English Engineering units.

RETURN

OVERLAY DESCRIPTION

As a result of adding the two additional subroutines for predicting the thermal conductivity of a mixed gas (TCMG and INTERP), the overall length of our predictive program has exceeded the maximum allowable program length of 32,000 words (two bytes per word) that is allowed by the RSX-11M operating system [7]. Therefore, to have the mixed gas program (MGMOD) task build successfully with the RSX-11M task builder program (TKB), an overlay structure [7] had to be defined.

An overlay structure defines which program modules (subroutines, functions, or main) are logically independent and, thus, may occupy the same memory space when the overlayed task is executed. The overlay description language (ODL) requires that each program module exist in an independent object file; thus, to facilitate the development of the overlay description, the mixed gas program (MGMOD) was divided into twelve independent modules. The modules are named:

MHLMOD	TCMG
REINIT	INTERF
OHTC	TR
FUNCTF	PRED
CHTC	PLOTD
TC	PLOTN

Each source code file ends with the FTN extension and each object file, which is the output from the F4P task [8], ends in the OBJ extension.

To create the overlayed executable task (MGMOD) the overlay structure that is desired must be described by using the Overlay Description Language (ODL) [7]. This overlay description must define all of the files that are needed to task build the program; the name of this overlay description file is expected to end with an extension of ODL. Table 1 displays the command sequence necessary to invoke the task builder program (TKB) when an overlay description file is used.

Table 1

Task Builder Program (TKB) Command File

MCR>TKB
TKB>MGMOD.TSK,=MGMOD.ODL/MP
ENTER OPTIONS:
TKB>MAXBUF=292
TKB>ACTFIL=5
TKB>//

The /MP switch (Table 1) is applied to the input file to denote it as an overlay description file. This switch also causes the TKB program to proceed to ENTER OPTIONS: without the need of the single slashed (/) line (See reference 7 for details.). The MAXBUF=292 option is to allow the executable task to read or write data files which have input or output record lengths of up to 292 bytes. This length was chosen to correspond with the length of our experimental data records. The ACTFIL=5 option allows five files to be open simultaneously. This is necessary when creating plots to compare experimental and predicted data.

The overlay description file (MGMOD.ODL) describes the manner in which to organize the various modules in the executable task. As indicated earlier,

for the modules to be overlayed, they must be logically independent; for the modules to be logically independent, they must not access one another in any way, neither directly nor indirectly. Thus, the overlay file describes which modules may overlay one another during execution because of their complete independence. The contents of MGMOD.ODL are in Table 2.

Table 2 Overlay Description File

.ROOT MHLMOD-PSUB-MAIN-SPC-*(OHTCC,PLOTC,TRC)

PSUB: .FCTR [1,1]PLTUSL/LB

MAIN: .FCTR [1,1]SYSLIB/LB:\$SHORT SPC: .FCTR TC-TCMG-INTERP-REINIT

OHTCC: .FCTR OHTC-CHTC-FUNCTF

.NAME NULL

PLOTC: .FCTR NULL-(PLC:D-PSUB,PLOTN-PSUB)

.FCTR TR-PRÉD TRC:

.END

The various commands (.ROOT, .FCTR, .NAME, and .END) in the overlay description file (Table 2) are described in the RSX-11M Task Builder Reference Manual [7] in the section entitled "Overlay Description Language (ODL)."

By using the TKB commands described in Table 1 with the overlay description file of Table 2, the twelve cited modules may be linked into an executable task (MGMOD.TSK) which does not exceed the RSX-11M operating system's restriction of a maximum task size of 32,000 words. The overlay described above was developed solely for the DEC RSX-11M operating system; application to another computer system will require modification of the overlay structure. It may be possible to eliminate the overlay structure if a computer's operating system allows all of the modules to be built into a single sequential program.

REFERENCES

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